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| FRANZ, W.A. | | |
| HANNI, B.J. | | |
| HEALY, T.J. | | |
| HEDAHL, T.G. | | |
| HILBIG, J.G. | | |
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| KELL, R.E. | | |
| KIRBY, W.A. | | |
| KUESTER, A.W. | | |
| MAHAFFEY, J.W. | | |
| MANN, H.P. | | |
| MARX, G.E. | | |
| McKENNA, F.G. | | |
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| PIZZUTO, V.M. | | |
| POTTER, G.L. | | |
| SANDLIN, N.B. | | |
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2-15-94 DATE BY

Ref Ltr. # 05327 RF93

DOE ORDER # 5400.1

RF-46522 (Rev. 01/94)

States Government

# Memorandum

**Department of Energy**
**Rocky Flats Office**

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ER:BKT:01234

EG&G Memorandum 93-RF-15624 (SGS-667-93) dated December 22, 1993, Statistical Methodology for Background Comparisons

Sue Stiger, Associate General Manager
Environmental Restoration Management
EG&G Rocky Flats, Inc.

We have reviewed the above-referenced memorandum from EG&G regarding the statistical methodology for comparing Operable Unit (OU) RFI/RI data with background data. The comment responses and revised methodology attached to SGS-667-93 have been reviewed by the U.S. Department of Energy, Rocky Flats Office (DOE/RFO). We continue to have problems with several responses to U.S. Environmental Protection Agency (EPA) and Colorado Department of Health (CDH) comments and the corresponding text in the methodology. I am concerned that previous DOE guidance to EG&G (memorandum ER:BKT:13980) on this subject has not been implemented, which may be generating avoidable costs.

Please find attached DOE/RFO comments on the attachments to the above-referenced memorandum. We request that responses to EPA and CDH comments be revised per the attached comments. In addition, we request that the statistical methodology be revised in accordance with DOE/RFO, EPA and CDH comments.

Additional inconsistencies and problems have been noted in the statistical methodology document. These have been identified in the DOE/RFO comments on Attachment C. We request that EG&G revise the methodology such that the inconsistencies and problems are resolved as requested.

We request that revised responses to EPA and CDH comments along with a revised statistical methodology be provided to DOE/RFO by March 4, 1994.

Shirley Olinger
Assistant Manager for
Environmental Safety and Health

Attachments

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ADMIN RECORD
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S. Stiger
ER:BKT:01234



cc w/ Attachments:
G. Hill, ESH, RFO
A. Howard, ESH, RFO
B. Thatcher, ER, RFO
J. Hopkins, EG&G

cc w/o Attachments:
M. McBride, AMER, RFO
R. Schassburger, DAMER, RFO

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DOE RFO COMMENTS ON RESPONSES ATTACHED TO SGS-667-93
ATTACHMENT A

1) EPA Specific Comment 1 - You have not responded to their suggestion that the same field sampling and laboratory procedures be used for both background and site data. DOE/RFO agrees with this comment. This is truly a background comparison issue. Provide an accurate and appropriate response to this comment.

2) EPA Specific Comment 2 - Essential nutrients have not been eliminated from the protocol in the statistical methodology. State this fact in your response. Also state that EPA withdrew this comment at our September 29, 1993 meeting.

3) EPA Specific Comment 6 - EPA, CDH and DOE/RFO agreed at our September 29, 1993 meeting that DQOs were an important issue, but should be dealt with independently from the statistical methodology. State this in your response.

4) EPA Implementation Issue 3 - See DOE/RFO comment immediately above regarding DQOs. Restate here.

5) EPA Implementation Issue 5c - This conflicts with the response to EPA Implementation Issue 1. Eliminate the inconsistency in both the responses to comments and in the statistical methodology document. There is confusion regarding detection vs. reporting limits.

6) You have not responded to EPAs general comments in their September 21, 1993 letter to DOE/RFO. Provide written responses to their general comments.

7) CDH Comment 4 - See DOE/RFO comment 5 above. Be consistent.

DOE/RFO COMMENTS ON RESPONSES ATTACHED TO SGS-667-93
ATTACHMENT B

1) CDH Comment 9 - Your response is counter to prior written direction from DOE/RFO. Move the Preliminary Exploratory Data Appraisal to the Data Presentation Section as requested by CDH. A meeting is not appropriate as this issue has been previously discussed between EG&G and DOE/RFO.

2) CDH Comment 10 - Your response is counter to prior written direction from DOE/RFO. State in your response and in the statistical methodology document that this information will be informally discussed with EPA and CDH at a meeting with DOE/RFO. We do not have to commit to a formal written deliverable. A meeting is not appropriate as this issue has been previously discussed between EG&G and DOE/RFO.

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DOE/RFO COMMENTS ON ATTACHMENT C

1) Figure 1-2 - This figure refers to how the 1993 Background Report proposed that these comparisons be made and is not discussed in the methodology document. Thus, we request that this figure be deleted from the methodology document.

2) The first paragraph of page 2 states that the background data sets will be taken from the 1993 Background Geochemical Report. However, the surficial soil data from Rock Creek and the associated UTLs were not included in this report. In addition, no provision is made for supplementing these data with the planned background surficial soil sampling for FY 94. The text should be corrected to reflect these items.

3) The first paragraph under "Data Collection and Validation" on page 2 states that data will be used for OU comparisons without waiting for 100% validation. It further states that the impacts of using non-validated data will be discussed on a case-by-case basis. This may result in a complete rerun of the statistical comparison of background and RFI/RI data if only a few percent of the data are rejected in the validation process. The individual OU Workplans, QAPjP, and QA Workplan addenda should be reviewed regarding the use of rejected data. The methodology should state that the OU Workplan, QAPjP and QA addenda will be reviewed prior to using rejected data.

4) The last sentence on page 5 states that a discussion of detection limits will be given, but the discussion was not included. We request that this discussion be provided.

5) All figures in the statistical methodology document should have both figure numbers and consistent captions. Correct this situation.

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# EG&G ROCKY FLATS

EG&G ROCKY FLATS, INC.
ROCKY FLATS PLANT, P.O. BOX 464, GOLDEN, COLORADO 80402-0464 • (303) 966-7000

0000022323

December 22, 1993

93-RF-15624

Martin H. McBride
Acting Assistant Manager for
Environmental Restoration
DOE, RFO

RESPONSE TO COMMENTS (13980) - SGS-667-93

Attached please find responses to comments made in the referenced memorandum (EG&G Responses to Environmental Protection Agency and Colorado Department of Health Comments on Statistics Strawman (NMH-606-93) dated November 30, 1993).

All of the comments have been addressed in the attachments to this letter, with the exception of comments 9 and 10 of the Colorado Department of Health comments dated October 13, 1993. We request a meeting between EG&G personnel and B. K. Thatcher of the Department of Energy, Rocky Flats Office early in January 1994 to resolve comments 9 and 10. EG&G will contact Mr. Thatcher to arrange this meeting.

This letter has three attachments. Attachment A contains the responses to the earlier Environmental Protection Agency and Colorado Department of Health comments, which addressed Dr. Gilbert's proposed methodology. Attachment B contains responses to agency comments on the Strawman document and Attachment C contains the statistical methodology itself; both attachments B and C were modified per the referenced letter.

Although comments 9 and 10 of the Colorado Department of Health comments remain outstanding, we plan to proceed with the background data comparison methodology as presented in Attachment C, to minimize schedule impact. If you have any questions or require further information please call Steve Needler of Environmental Engineering & Technology at X6961.

S. G. Stiger
Associate General Manager
Environmental Restoration Management

SPN:cet

Orig. and 1 cc - M. H. McBride

Enclosures:
As Stated (3)

cc:
A. H. Pauole - DOE, RFO
R. J. Schassburger - DOE, RFO
M. N. Silverman - DOE, RFO
B. K. Thatcher - DOE, RFO

6

United States Government

**Department of Energy**

# memorandum

**Rocky Flats Office**

DATE: DEC 1 7 1993

REPLY ATTN OF: ER:BKT:13980

SUBJECT: EG&G Responses to Environmental Protection Agency and Colorado Department of Health Comments on Statistics Strawman (NMH-606-93), dated November 30, 1993

TO: Ned Hutchins, Acting Associate General Manager
Environmental Management
EG&G Rocky Flats, Inc.

This memorandum is in response to the above-referenced document from EG&G regarding the statistics strawman outlining the methodology for comparing Operable Unit RFI/RI data with background data. You should note that prompt resolution of this matter is necessary so that work can proceed on background comparisons.

The initial DOE/RFO memorandum requesting responses to Environmental Protection Agency (EPA) and Colorado Department of Health (CDH) comments was ERD:BKT:12637, dated November 3, 1993. We also requested that responses to comments be prepared for EPA and CDH comments on Dr. Gilbert's proposed methodology, dated July 30, 1993. These comments were dated September 13 and 21, 1993, respectively, and were provided as attachments to our memorandum. No responses to these comments have been provided as requested by DOE/RFO. You are currently approximately one month behind on this task. We request that EG&G prepare responses to these comments immediately and that the responses accompany the final revision of the statistics methodology.

Members of our staffs met on December 14, 1993, to discuss the responses to comments and the statistics methodology contained in your November 30, 1993 memorandum. The attached comments were verbally presented to EG&G at this meeting. Please find attached DOE/RFO comments on your responses to EPA and CDH comments, dated October 25 and 13, 1993, respectively. Several responses do not adequately address concerns expressed by EPA and CDH. In addition, the statistics methodology does not reflect their concerns. We request that EG&G modify the responses and the statistical methodology per the attachment. In addition, we request that DOE/RFO comments on the statistics methodology be incorporated.

All responses to comments and modifications to the statistics methodology requested in this memorandum should be transmitted to DOE/RFO by December 24, 1993.

# ATTACHMENT A

RESPONSES TO EPA LETTER 8HWM-FF - STATISTICAL COMPARISONS TO BACKGROUND AT ROCKY FLATS DATED SEPTEMBER 21, 1993 AND TO CDH LETTER - STATISTICAL METHODS FOR THE COMPARISON OF REMEDIAL INVESTIGATION DATA TO BACKGROUND DATA AT ROCKY FLATS PLANT, DATED SEPTEMBER 13, 1991

**RESPONSES TO EPA LETTER 8HWM-FF - STATISTICAL COMPARISONS TO BACKGROUND AT ROCKY FLATS DATED SEPTEMBER 21, 1993:**

SPECIFIC COMMENTS

1. Page 2, Seventh Bullet. It is suggested that the same field sampling and laboratory procedures be used for both background and site data. The statement should be extended to include data aggregation. Past review of RFP data from operable units showed inconsistencies in the methodology used to aggregate data. Problems encountered at this phase will be magnified at later stages of the background analysis.

**Clarification.** Data aggregation is another topic, being addressed by CDH and EPA separately from this forum, which deals strictly with site-to-background comparison.

2. Page 4, Task 1, Observation 1, Third Bullet. This statement suggests that background analysis should be the initial state in selecting COCs. This is consistent with the COC selection methodology developed for Rocky Flats by DOE, EPA, and CDH. However, in order to manage DOE's effort in background comparisons, we point out that it is not necessary to carry all chemicals through an elaborate, time consuming statistical analysis if they can be eliminated as essential nutrients or as infrequently detected chemicals. It may be more cost-effective and expeditious to simply eliminate chemicals on the basis of these two preliminary criteria than to conduct a background analysis only to eliminate them later based on the background analysis. We suggest that DOE consider this in the development of a plan to implement Dr. Gilbert's approach.

**Concur.** CDH is correct that time might be saved in eliminating nutrients and infrequently detected analytes prior to statistical analysis. We will investigate whether significant time is saved by following CDH's recommendation, and if so, will adopt the suggestion.

3. Page 5, Task 1, Observation 4, Second Bullet. This statement expresses concern about measurements that are less than the contract required detection limits (CRQL) but above instrument detection limits (IDL). According to Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Volume I, Part A, these measurements should be "J" coded and interpreted as estimated values. They should not be viewed as non-detected chemicals. If they are currently classified as non-detect chemicals in the RFP background geochemical report, the entire validation process currently in place should be reevaluated.

**Clarification.** There has been confusion over the detection limits and their application. A qualifier of "J" indicates that the reported value is between the instrument detection limits and the contract required detection limits. A non-detect has a reported value of a detection limit, not the detected value, and conveys less information than a "J".

4. Page 9, Paragraphs 3 and 4. The essence of this discussion is that a hot measurement (HM) concentration should serve as a "safety net" that can prevent "hot spots" from passing

unnoticed in a risk assessment. It should be noted that this need has been previously recognized and was addressed in the original flow chart devised during the summer 1992 meetings involving EPA, DOE, and CDH. At that time, it was agreed that a risk-based concentration (RBC) would effectively serve as the "hot measurement." Although a UTL has some utility in identifying hot spots, there is no need to conduct a lengthy analysis if the highest detected concentrations do not exceed a predetermined RBC and pose an unacceptable human health risks. Thus, it is possible to have measurements above the UTL but below an RBC in which case there would be little reason to consider the chemical further.

**Clarification.** The Guide for Conducting Statistical Comparisons of RFI/RI Data and Background Data at the Rocky Flats Plant (called The Guide subsequently) addresses statistical determination of the presence or absence of analytes, and does not address human health effects. For each OU, additional tests will determine if the analyte concentrations present are below regulatory (ARARs) and/or human health effect (PRGs) levels, but that is external to the statistical discussion at hand.

5. Page 10, Third and Fourth Bullet. This statement refers to lowering the potential for a Type I, false positive error to using a 99 percent UTL on the 99 percentile. However, this concern is not properly balanced against the potential for a Type II error. A false negative could have profound consequences on the risk assessment and subsequent remedy selected for the site.

**Do not concur.** If the 95% UTL were used, then a very high percentage of data points would be considered pCoCs, because theoretically, even a background population will have 5% of readings above the UTL. A site, even if its concentration levels are slightly above background, may have considerably more than 5% of its readings above the $UTL_{95/95}$. Any analytes that show a false negative on this test will still be considered pCoCs if they test positive on any of the other statistical tests.

6. Page 11, Second Paragraph. This paragraph suggests that data quality objectives (DQOs) be established at the design stage of the studies. Although this is a relevant comment in the context of planning a background analysis, the background and most of the OU planning and sampling has already been completed. Thus, this comment is appropriate in theory but there is little chance for implementation. Revitalized effort should be directed to establishing DQOs where they were not previously established, and analyzing whether the sampling efforts completed to date have succeeded in meeting these DQOs. DOE, EPA, and CDH will need to look at options for correcting the situation if the DQOs have not been met.

**Concur.** The draft RIs for each OU have a section for reviewing data quality. Each OU manager bears the responsibility for ensuring that DQOs are met for his or her OU.

7. Task 4, Flow Chart for Comparing OU Data to Background. With a minor exception, this flow chart adequately describes the framework for a background analysis. The exception is an inadequate description of appropriate conditions under which particular statistical tests should applied.

Explicit guidelines for the application of specific statistical tests under well-defined conditions

10/65

should be presented to circumvent future misunderstandings: It would be highly useful for EPA, DOE, and CDH to agree to a predetermined paradigm in which all possible circumstances and conditions have been anticipated and the appropriate statistical tests identified. Knowing in advance what particular test will be applied under what circumstances will prevent protracted discussions and possible disagreements.

**Concur.** The Background Comparison Methodology chart shows the specific tests and gives the conditions under which they are or are not applicable. In addition, The Guide's text states which tests will be conducted, under what circumstances.

## IMPLEMENTATION ISSUES

1. EPA, DOE, and CDH must reach consensus on procedures for defining non-detects.

**Concur.** The Guide states that non-detects will be considered to be one-half of the detection limit, in accordance with EPA guidance.

2. EPA, DOE, and CDH must reach consensus on what hot measurement value should be used.

**Concur.** Our methodology uses a value of $UTL_{99/99}$ .

3. EPA, DOE, and CDH must establish data quality objectives which address acceptable power and confidence levels, required detection limits, and anticipated data aggregation.

**Concur.** The draft RIs for each OU have a section for reviewing data quality. Each OU manager bears the responsibility for ensuring that DQOs are met for his or her OU.

4. EPA, DOE, and CDH must revisit the assumptions which Dr. Gilbert lists on page two of his cover letter. Are these assumptions valid? What are the consequences if the assumptions are violated? Can this be handled in an uncertainty analysis?

**Clarification.** All of the assumptions listed, except for the last four, are difficult to quantify and are thus not "valid" or "invalid". These last four are now answered individually.

The same field-sampling techniques are used for background and site, so this assumption is valid.

Measurements are not always validated by subcontractors before the draft RFI/RI statistical testing has been completed, so this assumption is not valid. When the data validation results have been obtained, the data are reanalyzed, and the final RFI/RI contains no invalidated data.

Background data were checked for outliers, per EPA comments upon the 1992 Background Geochemical Report, and extreme outliers were excluded from statistical analysis in the 1993 Backgroun Geochemical Report, so this assumption is not entirely valid. However, OU data outliers are not typically deleted, although data from the OUs are checked for "geochemical reasonableness", and any unusual results are discussed in the ensuing reports.

The instrument detection limits are not always reported in the data bases, so this assumption is not completely valid. However, the costs of recovering this information would be considerable.

5. EPA, DOE, and CDH must reach consensus on a paradigm for implementation. The issues to be worked out include:

a. The appropriate background data sets by analyte, medium, and location.

12

12/65

**Concur.** The section of The Guide entitled "Determine Background and OU Target Populations" addresses how this will be done.

b. How to deal with clearly non-random (e.g., spatial) patterns.

**Concur.** The Guide states in the Professional Judgement section that spatial patterns are subject to professional judgement, which is then subject to EPA and CDH review.

c. Measurement errors and multiple non-detects.

**Concur.** Measurement errors are an inevitable part of physical data. Efforts are taken throughout the data-collection process to minimize errors. Multiple non-detects are dealt with by replacing the data value with ½ of the reported value, or by using the Gehan test.

d. Structure for the formal statistical tests.

**Concur.** The Guide furnishes this structure.

e. Data aggregation for comparison in the statistical tests.

**Clarification.** Data aggregation is another topic, being addressed by CDH and EPA separately from this forum, which deals strictly with site-to-background comparison.

RESPONSES TO CDH LETTER - STATISTICAL METHODS FOR THE COMPARISON OF REMEDIAL INVESTIGATION DATA TO BACKGROUND DATA AT ROCKY FLATS PLANT, DATED SEPTEMBER 13, 1991

1. The Division would like to emphasize the importance of effective graphical presentation of data to enhance the understanding and interpretation of the statistical tests. The Division believes that the development of effective graphical procedures to display and interpret both site and background data is essential to the usefulness of the methodology and should not be overlooked or down-played. The Division requests that specific graphical techniques be developed and included in the "statistical strawman" methodology.

**Concur.** The Guide specifically addresses graphical techniques.

2. The Division does not recommend the use of a risk based hot measurement comparison value in the hot measurement comparison. The use of risk based decisions is not appropriate in the context of comparisons to background.

**Concur.** The hot-measurement comparison value is not risk-based.

3. As noted in Dr. Gilbert's report, the proper treatment of non-detects and multiple detection limits is critical to the implementation of his recommendations. Both of these issues occur frequently in Rocky Flats data sets. Therefore, the Division recommends that DOE emphasize specific protocol for proper treatment of non-detects and multiple detection limits in the "strawman" methodology.

**Concur.** The Guide states that non-detects will be dealt with by replacing the data value with ½ of the reported value.

4. The Division agrees with Dr. Gilbert that professional judgement is necessary in evaluating the results of statistical tests. However, it is not the Division's intention that professional judgement be a substitute for an inadequate site investigation or as a tool to dismiss dubious data. The scope of appropriate professional judgement and limitations on its application should be outlined in the "strawman" methodology. Guidelines and criteria for making decision based on professional judgement should also be identified.

**Concur.** The Guide restricts professional judgement to several specific areas.

ATTACHMENT B

Responses to EPA: Hestmark letter 8HWM-FF received 10/25/93 and to CDH letter "DOE Proposed Methodology for Statistical Comparison of Remedial Investigation Data at the Rocky Flats Plant" from G. Baughman to R. Schassburger, dated 10/13/93

Response to EPA: Hestmark letter 8HWM-FF received 10/25/93

1. To determine the appropriate background and operable unit populations for comparison, we understand that some matching of the two populations is done by geologists and chemists. Data for an analyte in a non-background area are grouped according to a combination of background classes which represent independent background populations. A table that cross references the operable unit populations and the background populations will be provided.

> **Concur.** The strawman has been changed to require tables that cross-reference OU media to background media.

2. A more explicit statement of the null hypothesis that is being tested will be included. In addition, a fixed p value of 0.05 will be used for each of the inferential statistical tests as written in the strawman proposal. There was some inconsistency in what was written in the proposal and what was stated in the meeting regarding the p value. A fixed value of 0.05 is what we will accept.

> **Concur.** The strawman states that p values must be less than or equal to 0.05 to demonstrate a significant difference from background. Footnote 3 on page 5 of the strawman, which was not clear on this point, has been deleted.

3. All references to comparison of background and operable unit populations for organics will be removed. Background comparisons apply to inorganics and radionuclides only.

> **Do not concur.** Although background comparisons for organics are not commonly used, there are instances when it may be applicable, in which wide-ranging organic contamination is due to non-site-specific anthropogenic sources. We want to retain the option of performing background comparisons for these organics, when geochemists or geologists determine that it is applicable to do so. In these instances, we will retain the burden of proof, and the applicability of the comparison will be subject to EPA and CDH approval.
>
> The strawman has been rewritten to state that background comparisons for organics will be done on a limited, case-by-case basis, subject to EPA and CDH approval.

4. The use of professional judgement in interpreting the results of the graphical displays and statistical analyses will be limited to consideration of spatial distribution, temporal distribution, and pattern recognition concepts. The strawman proposal included five additional criteria. These will be deleted in the final implementation document.

> **Concur.** The five criteria (intermedia interactions and geochemical processes, not an expected contaminant, blank data, regional background range, and influence of field activities) have been deleted.

parameters. The quantile test could be correctly applied only if the largest n values were all detects. Our statisticians have stated that, typically, this restriction equates to the largest 20% or less of the combined sample sizes being detects, and recommend using a flat 20% to simplify application.

c. What is the basis for the criteria of $N > 20$ value for background and operable unit data?

**Clarification.** Our statisticians derived this value from application of the Central Limit Theorem for a two sample problem. If both samples have $N=20$, then there will be 38 total degrees of freedom, which will permit assumptions about the distribution.

7. EG&G's claim that these impacts [of implementing Dr. Gilbert's recommendations] could range from $30,000 up to $120,000 per operable unit is not supported by the information provided. In fact, it appears that there is some evidence that implementation will not negatively impact costs or schedules.

**Do not concur.** Because the Gilbert method requires additional work, there will be cost and/or schedule impacts.

In addition to the impacts mentioned above, cost impacts may result if the Gehan method is used. For OU11, approximately 200 hours were required to perform the Gehan test, when less than 40 hours would have been sufficient to perform standard ANOVA testing. However, the majority of these costs appear to be one-time costs such as coding development. Subsequent testing on the same OU indicate that the cost impacts may be as little as 30 hours for a small data set.

5. The non-background population is defined as the entire operable unit remedial investigation set. The data aggregation for the purpose of background comparison will be done within the area defined by the operable unit boundaries.

**Concur**. Analysis will be done on an OU-wide basis.

6. The attached flowchart, "Background Comparison Methodology", distributed at the meeting will be clarified. It is EPA's understanding that all the data sets will undergo the hot measurement test and the battery of inferential statistical tests (Gehan, Quantile, Slippage, and T-Test) provided the data satisfies the conditions stated in the strawman and on the flowchart. If any one of these tests, including the hot measurement test, shows significance, the analyte will be further considered, using professional judgement, as a contaminant of concern. The flowchart would benefit from the addition of decision blocks after each test indicating the next step if significance is demonstrated or not.

**Clarification.** The chart "Background Comparison Methodology" attached to EPA's memo is not the same as that distributed at the September 29, 1993 meeting and contained within the strawman proposal. The difference is that nonparametric ANOVA tests are given as options to the Gehan test in the chart within the strawman proposal. Because the Gehan method is not standard and will therefore incur practical liabilities (e.g., the method has not been adequately tested and verified, preliminary usage shows it to require excessive man-hours, and subcontractors will need to be instructed in its use), we want to retain the option of performing standard nonparametric ANOVA testing, using the Wilcoxon or Kruskal-Wallis tests, instead of the Gehan test.

**Additional clarification.** The suggested decision blocks are not necessary. All tests will be performed, if applicable, regardless of whether other tests demonstrate significance.

**Concur** with the need to redo the flowchart. This has been done.

6. (continued) We also have some specific questions that need to be addressed in the final document:

a. What happens to data which is carried through the slippage test but does not qualify for the t-test?

**Clarification.** The data that do not qualify for the t-test will be routed to the "At Least One Test Significant?" block. The flowchart has been revised to show this.

b. What is the basis for the 20% detect value as the criteria for the Quantile test? How does this criteria relate to the criteria for applying this test as stated in Dr. Gilbert's report on page 20?

**Clarification.** Dr. Gilbert's method proposed looking up tabulated values for n and r



18/65

Response to CDH letter "DOE Proposed Methodology for Statistical Comparison of Remedial Investigation Data at the Rocky Flats Plant" from G. Baughman to R. Schassburger, dated 10/13/93

1. To minimize any potential future misunderstandings of this agreement, the Division feels that it is critical for the Agencies to develop a formal guidance/policy document institutionalizing the agreement. The Strawman document was written for the purpose of facilitating agreement among the Agencies. However, the end users of this document will be the operable unit managers and sub-contractors preparing and reviewing RFI/RI reports. The majority of these people were not involved in the development of this methodology. It is critical to the future of this agreement that final documentation of this agreement be developed to clearly and concisely guide future end users in the implementation of this methodology. This formal guidance should be completed in parallel with the implementation of the agreement.

> **Concur.** When the strawman has been completed and accepted by all concerned parties, it will then be rewritten as a procedure for statistical comparison of OU data to background.

2. The Division recommends that the title of this document be revised to more accurately reflect its content and intent, that being methodology and guidelines for the comparison of site data to background data. The Division proposes the title, "Guide for Conducting Statistical Comparisons of RFI/RI Data and Background Data at the Rocky Flats Plant," for consideration.

> **Concur.** The CDH's proposed title is an improvement to the current title, and has been adopted.

3. One of the central themes of Dr. Gilbert's recommendations was the need for statisticians to be involved throughout the entire process. However, statistician involvement is not discussed in the methodology. The division requests that the role of the statistician in implementation of this methodology be clarified in this document.

> **Concur.** Statisticians will be employed to verify that the methods used are correct. The strawman has been rewritten to incorporate this.

4. The Division does not believe that references to specific DOE sub-contractors are appropriate in this document. The Division recommends DOE review all references to sub-contractors and, where appropriate, modify the reference to more accurately reflect DOE's role and responsibilities.

> **Concur.** References to DOE subcontractors have been eliminated.

19 11/65

5. This section (Determine Background and OU Target Populations) outlines the steps for matching site and background populations. However, it is unclear exactly how the matching will be implemented. The Division recommends that the rationale for combining media/geology groupings for testing be detailed in this section. For example, any criteria for minimum group size necessary for statistical testing should be specified. The Division further recommends adding a table or diagram depicting the general rationale for grouping data by media and geology.

**Concur.** The strawman states that the OU will match one or more of several specified background media. In addition, the strawman has been changed to require that a cross-reference be performed between the site and one or more background media.

6. As discussed during the September 29th meeting, and emphasized by Dr. Gilbert, it is critical to statistical hypothesis testing that the hypothesis to be tested is explicitly defined and clearly stated. The Division recommends a statement of the test and null hypotheses, in both "english" (narrative qualitative description) and statistical terms, be added to this section of the methodology so there is no misunderstanding of what is being tested. This statement should also address confidence and power requirements for the tests.

**Concur.** The strawman has been modified to require statistical and prose statements of the null and alternative hypotheses.

7. The Division does not agree with the blanket statement at the beginning of this discussion, "Under current IAG schedule conditions, analytical data will not be 'validated' when the background comparisons will be made in each draft report." This claim is not substantiated by the schedules submitted by DOE in the approved OU work plans and is in direct contradiction to Dr. Gilbert's Task 5 recommendations. Dr. Gilbert states that, "These data quality evaluations are conducted prior to descriptive graphical analyses and formal statistical tests." In finalizing this methodology, the Division recommends that DOE follow Dr. Gilbert's recommendations for data validation <u>before</u> formal graphical presentation and statistical testing. The need for variance from this approach will be considered by the Division on an OU specific basis.

**Do not concur.** Under the present system of data validation, the non-validated data are used only for the draft RFI/RI. The final RFI/RI is based solely upon validated data. The lag time between receiving data from the laboratory, and validated data from the independent subcontractor can exceed one month. Waiting for 100% validation may impact schedules, but will probably not change the results in the final RFI/RI. The potential impacts of using non-validated data at each OU will be discussed on a case-by-case basis.

8. The Division recommends DOE add a discussion of detection limits to this section of the methodology. In the past there has been confusion as to what detection limits are being reported and used (instrument detection limits vs contract limits vs reporting limits). Part of this confusion may be because detection limits have not been formal discussed. This section

should state what detection limits are to be used in statistical testing and how they are determined from the RFEDS data set.

> **Concur.** The strawman addresses detection limits, and it specifies how determinations are made on how to handle non-detects.

9. The Division recommends that this section (Preliminary Exploratory Data Appraisal) be moved to the Data Presentation section.

> **Clarification.** The Data Presentation section consists entirely of deliverables to the EPA and CDH. The preliminary exploratory data appraisal is intended for the use of the analyst only, and does not necessarily constitute a deliverable. For this reason, we have chosen to segregate the two sections.

10. The Division interprets this section as describing the informal data analysis conducted during RFI/RI preparation and not normally included in the formal RFI/RI report. The Division recommends adding language to indicate that this informal data analysis will be made available and reviewed with the regulators in evaluating the appropriateness of the scope of the formal RFI/RI proposal.

> **Do not concur.** We have provided this section for information only. Its products are not intended to be deliverables. If they were to be deliverables, this would impact the schedule of analysis. We have added language to this section to clarify this.

11. The Division does not agree with DOE's recommendations that box plots are applicable only when there are no non-detects. The problem of estimating percentiles for data sets with multiple non-detects was not resolved by Dr. Gilbert. The Division recommends that when a reasonably small percentage of non-detects are present, percentiles be estimated using Maximum Likelihood Estimation (MLE) techniques in constructing box plots.

> **Concur.** We will provide box plots unless the percentage of non-detects exceeds 50%. The 50% figure is chosen for consistency with the 1993 Background Geochemical Characterization Report (September 30, 1993).

12. The Division does not agree with DOE's suggestion that histograms are not useful for small or highly censored data sets, such as inorganics. As stated by Dr. Gilbert, such histograms are not likely to be useful in visually assessing whether the data sets are better modeled by a normal or lognormal distribution. However, they may still be useful to visually compare the spread, central tendency, and skewness of the two data sets to look for differences that may be important.

> **Concur.** We will provide histograms unless the percentage of non-detects exceeds 50%. Bars in the histogram will be shaded to indicate the percentage of detects and non-detects within each bar interval.

13. The Division recommends that a discussion be added to this section of the methodology



2/16

to address what to do when a UTL 99/99 can not be reasonably estimated or is unknown (ie small or highly censored background data set).

**Concur.** We have modified the strawman to state that professional judgement, and use of geochemical background data from the literature, will be used. The result will be a geochemical interpretation of data, subject to agency review and approval.

14. The reference in Footnote 2 to OU 1 is not appropriate and should be removed. The inferential tests conducted at OU 1 were the result of a compromise agreement, are not precedent setting for other OUs and are not the tests being proposed in this document. However, as stated in this note, limited professional judgement as presented later in this document may be applicable.

**Concur.** This footnote has been deleted.

15. This discussion (Footnote 3) should be moved to the DQOs or statistical test definition section of the document.

**Clarification.** This footnote has been deleted. We intend to use a p value of 0.05, and the footnote made that intent unclear.

16. The Division does not agree with the limitations DOE has placed upon the Slippage Test. The slippage test can be applied to data sets when the largest background point is a non-detect. If the largest background data point is a non-detect then logic must be applied to determine if the slippage test is applicable, but the test should not be categorically eliminated.

**Concur.** We have rewritten the strawman to state that, if the largest background data point is a non-detect, we will apply judgement to investigate whether or not the slippage test is applicable.

17. The Division recommends limiting the use of professional judgement to the first three criteria; spatial distribution, temporal distribution, and pattern recognition. In addition, it is recommended that the introduction to this section include acknowledgement that in applying professional judgement, the "burden of proof" lies solely on DOE. Professional judgement will only be considered by the Division on a limited basis where well documented and defensible evidence is presented.

**Concur.** We have eliminated the last five criteria from the strawman, and acknowledged that we will bear the burden of proof.

18. To make the process more efficient the task of eliminating non-detected analytes should be completed prior to data presentation. The flow chart should be modified to reflect this change.

**Concur.** We have changed the flowchart. CDH's comment improved the process.

19. This flow chart is confusing and difficult to follow due to the many multiple and undefined branches. To minimize the potential for misunderstanding this chart must either be clarified or deleted.

**Concur:** The flowchart is too important to delete. It has been clarified. Lines denoting the flow of information have been deleted, keeping only the lines denoting flow of control, in accordance with common flowcharting techniques. Decision blocks have been transformed into diamond shapes. Alternative "No" paths have been added for the blocks labeled "No Non-Detect Present...OU Data Normally Distributed?", and "At Least One Test Significant?" Finally, the block representing the conditions which must be met prior to performing the t-test has been changed to reflect the conditions given in the text.

ATTACHMENT C

GUIDE FOR CONDUCTING STATISTICAL COMPARISONS OF RFI/RI DATA AND BACKGROUND DATA AT THE ROCKY FLATS PLANT

Guide for Conducting Statistical
Comparisons of RFI/RI Data and Background Data
At the Rocky Flats Plant

## General

This document is intended to provide guidelines for OU-to-background comparisons of data, and to explicitly discuss approaches to the issue of determining OU-specific contamination. The OU-to-background comparison will be applied for inorganics and radionuclides. In addition, the comparison may occasionally be performed for organics on a limited, case-by-case basis, subject to EPA and CDH approval.

It is important to establish a common approach leading to a common list of possible contaminants for each OU. To this end, the Figure **GENERAL APPROACH TO DETERMINING "CONTAMINANTS"** was developed. In this general technique, a "Tool-Box" approach is employed to arrive at one common list of contaminants for each OU (or subdivision), for all functional aspects of the RFI/RI and CMS/FS.

As indicated, several disciplines such as the Human Health or Ecological Risk Assessors and Regulatory specialists may pare the list of contaminants to "Contaminants of Concern" (COCs) based on factors germane to their application (e.g., toxicity).

The text below follows **TASK 4: FLOWCHART FOR COMPARING OU DATA TO BACKGROUND.**

## Start

## Determine Background and OU Target Populations

Appropriate geographical, geological, and temporal data sets will be defined for comparison. This is essentially a matching exercise so that Site (OU) data sets are comparable to background sets. Consideration will be given to issues such as:

- Geologic materials
- Hydrostratigraphic unit
- Temporal comparability
- Sample size for statistical tests
- Confidence in geo/hydrologic regime determination

25/65

The background data sets will be taken from the 1993 Background Geochemistry Characterization Report (EG&G, September, 1993). The following media have defined backgrounds: groundwater (Rocky Flats Alluvium, valley fill alluvium, colluvium, weathered sandstone, and unweathered Arapahoe/Laramie formation rocks), surface water (Rock Creek and Woman Creek), seeps, stream sediments (Rock Creek and Woman Creek), seep sediments, and soils (Rocky Flats Alluvium, colluvium, surficial, weathered claystone, and weathered Arapahoe, Laramie sandstone). Site media will be cross-referenced to one or more background media.

## Set DQO's

DQOs are established to define data needs for each of the RFI/RI tasks, coordinate that collection activities support those needs, and ensure the quality and quantity of resultant data. Three stages are used in the development of DQOs:

**Identify Decision Types:**

Identify and involve data users,
Evaluate available data,
Develop a conceptual model of the study site, and
Specify RFI/RI objectives, and anticipate the decisions necessary to achieve the objectives.

**Identify Data Uses and Needs:**

Identify data uses,
Identify data types,
Identify data-quality needs,
Identify data-quantity needs,
Evaluate sampling and analysis options, and
Review data precision, accuracy, representativeness, completeness, and comparability (PARCC).

**Design Data Collection Program:**

Assemble data-collection components, and
Develop data-collection documentation.

## Data Collection and Validation

Under current IAG schedule conditions, analytical data may not be 100% "validated" when the background comparisons are made in each draft report. The potential impacts of using non-validated data will be discussed on a case-by-case basis.

A "preliminary" exploratory data appraisal will be performed to obtain a "feel" for the data. This will involve techniques and identification of issues such as:

Gross summary statistics
Spatial arrays
Temporal plots
Sampling strategy comparability evaluation
Affected media matrix
Hit ratios
Non-detect rates
Detection limit/quantitation limit issues
Extent of data qualifications "J", "B", etc.
Histograms/boxplots/other visuals
DQO adequacy/completeness assessment

This step will help guide the need for, and evaluate the appropriateness and applicability of further analysis, evaluate assumptions, and ascertain the impacts and limitations in light of the actual data as collected. Information generated during the exploratory data appraisal will be used in evaluating the appropriateness of the scope of the formal RFI/RI proposal. At the discretion of DOE and its contractor, it may occasionally be made available and reviewed with the regulators.

## Data Presentation

Several data-presentation techniques were identified by Dr. Gilbert as appropriate for different conditions. To perform them all for all compounds in a standard full suite is not necessary when it is clear from a preliminary review that the vast majority of data points for some compounds are entirely or almost entirely non-detects.

Accordingly, we have refined the methodology as follows:

**Box plots** will be used when the percentage of non-detects is 50% or less.

**Histograms** will also be used when the percentage of non-detects is 50% or less. Bars in the histogram will be shaded to indicate the percentage of detects and non-detects within each bar interval.

**Probability plots, ordered listings**, and other graphics will be used as appropriate.

As indicated by the OU1 process, visual presentation of the data is important. Interpretable graphics will be produced to the extent that they facilitate analysis. In general, graphics will be a central feature of analysis.

## BACKGROUND COMPARISON METHODOLOGY TOOL BOX APPROACH

Employing: Bounding-Benchmark Comparison (Hot Measurement), Inferential Statistics, and Professional Judgement

### General

The tool-box approach employs a bounding-benchmark comparison, inferential statistics, and professional judgement. This approach was forwarded in the OU1 comment-resolution process, endorsed by Dr. Gilbert, and is widely applied in the hazardous waste industry and environmental business across America. It employs a "weight-of-evidence" framework wherein all three aspects are factored into the determination of what is a Site (OU) contaminant. Statisticians will be used to verify that the methods used are correct.

### Bounding-Benchmark Comparison ("Hot-Measurement Test" Component)

- A hot-measurement test will be performed that will compare each analyte concentration to an upper-limit value for that analyte.

- The upper-limit value will be the value at which there is a 99% probability that 99% of the background distribution will be below this value ($UTL_{99/99}$). If the $UTL_{99/99}$ cannot be calculated or reasonably estimated, then background values from technical literature and professional judgement will be used. The resulting geochemical interpretation of data will be subject to Agency review and approval.

- The $UTL_{99/99}$ is required instead of a toxicity-based value because a single list of potential contaminants must be used by many disciplines (Human Health, Ecological, Regulatory, etc.,) to ensure consistency across the RFI/RI and CMS/FS Reports. The subjective nature of what is "hot", as well as toxicity and ARAR considerations, will be dealt with by the specialists who determine COC's specific to their discipline. See the Figure **UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT** for a comparison of UTL's and Human Health Toxicity-based "Hot-Measurement" values.

- In addition to ensuring that high concentrations do not get overlooked, the $UTL_{99/99}$ is an important tool for identifying locations of suspected elevated concentration in the "nature and extent" section.

28/65

Background Comparison Using Inferential Statistical Methods

Based on Dr. Gilbert's work, the following inferential statistical tests will be used to compare background data sets to data sets compiled at the Operable Units (OUs). These data sets will be compiled and compared by analyte, and by the correct background data set (i.e., colluvium, alluvium, alluvium + colluvium, surface soils, etc. [See Determine Background and QU Target Populations]).

It should be noted that Dr. Gilbert's recommendations establish a framework that emphasizes using the most appropriate test available. Thus professional judgement will be necessary both in application of inferential tests, as well as their interpretation. Additionally, within the framework of a battery of tests drawn from a "tool box" of methods, it is requested that EPA and CDH remain open to consultation on the use of other tests as appropriate.

The results of all tests (hot-measurement, inferential) will then be evaluated in light of professional judgement. This process is depicted on the figure **BACKGROUND COMPARISONS METHODOLOGY.**

If hot-measurement or inferential statistical tests show that the concentration of a given analyte in the OU data set is not greater than the concentration in the background data set, and if considerations in the professional-judgement arena do not override, then the analyte is considered not to be a contaminant.

If either the hot-measurement test or at least one inferential statistical test shows that the concentration of a given analyte in the OU data set may be greater than the concentration in the background data set, then professional judgement (using temporal and spatial analysis, as well as pattern-recognition concepts) is again applied to see if the analyte concentrations in the two data sets are actually different.

After the hot-measurement test and prior to the use of inferential statistical testing, the issue of non-detects must be dealt with for all tests except the Gehan test, which can be applied with non-detects present. For all other tests, non-detects should be replaced with a value of 0.5 times the applicable detection limit, following EPA guidance (Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance, July 1992), but realizing the performance of simple substitution decreases with an increasing proportion of non-detects.

The handling of non-detects, and the presence of multiple detection limits in the RFEDS data base, requires the use of good professional judgement along with the general guidance offered here. The use of graphical displays of data will assist in the handling of high-value non-detects.

A discussion of detection limits will be given at this point.

Gehan Test or Nonparametric ANOVA Test

- o The Gehan test is a nonparametric test and can be used when multiple detection limits are present. The Gehan test will be applied without replacing non-detects. These are the principal favorable attributes of the Gehan test.

- o Standard nonparametric ANOVA tests (Wilcoxon Rank Sum and Kruskal-Wallis) are widely used in environmental assessment, and are discussed in EPA guidance (Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance, July 1992). These tests require replacement of non-detect values, either by simple substitution or maximum-likelihood methods.

- o For the Gehan or nonparametric ANOVA test, a p-value will be generated and p-values that are equal to or less than 0.05 will normally be considered indicative of a significant difference from background. Statements of the test and null hypotheses will be given, in both statistical and narrative terms.

Quantile Test

- o The quantile test is also a nonparametric test and can be considered as a rapid screening test.

- o Due to limitations in the quantile test, the test will only be used if the largest 20% of the combined background and site data are detects.

- o A p-value will be generated and p-values that are equal to or less than 0.05 will indicate a significant difference from background. Statements of the test and null hypotheses will be given, in both statistical and narrative terms.

Slippage Test

- o The slippage test is a nonparametric test and can be considered as a rapid screening test.

- o Due to limitations in the slippage test, the test will possibly not be used if the largest background value is a non-detect. If the largest background value is a non-detect, then professional judgement will be applied to determine whether or not the slippage test is applicable. For example, if the second largest background value is a detect and is similar in value to the largest background value, it could be used in place of the largest value (although the replacement must be taken into account when interpreting the test results).

- o A p-value will be generated and p-values that are equal to or less than 0.05 will indicate a significant difference from background. Statements of the test and null hypotheses will be given, in both statistical and narrative terms.

T-Test

- The t-test is a parametric test and is very commonly used when testing the difference between means of two data sets.

- Due to limitations in the t-test, the test will be applied in cases where both background and OU data are normally distributed and contain at least 20 data points, and less than 20% of the background and OU data are classified as non-detects.

- A p-value will be generated and p-values that are equal to or less than 0.05 will indicate a significant difference from background. Statements of the test and null hypotheses will be given, in both statistical and narrative terms.

Due to their wide use in statistical applications, including regulatory settings, it is possible that ANOVA (parametric and non-parametric) tests may qualify as the most appropriate tests, notwithstanding their limitations with non-detects and multiple detection limits. DOE and its contractor shall confer with EPA and CDH, and seek regulatory assistance prior to the use of these tests, and any other tests deemed applicable, as appropriate. For example, see the attached Figure 1-2, **SELECTION OF STATISTICAL METHOD FOR COMPARISON OF BACKGROUND AND NONBACKGROUND POPULATIONS**, from the 1993 Background Geochemistry Report.

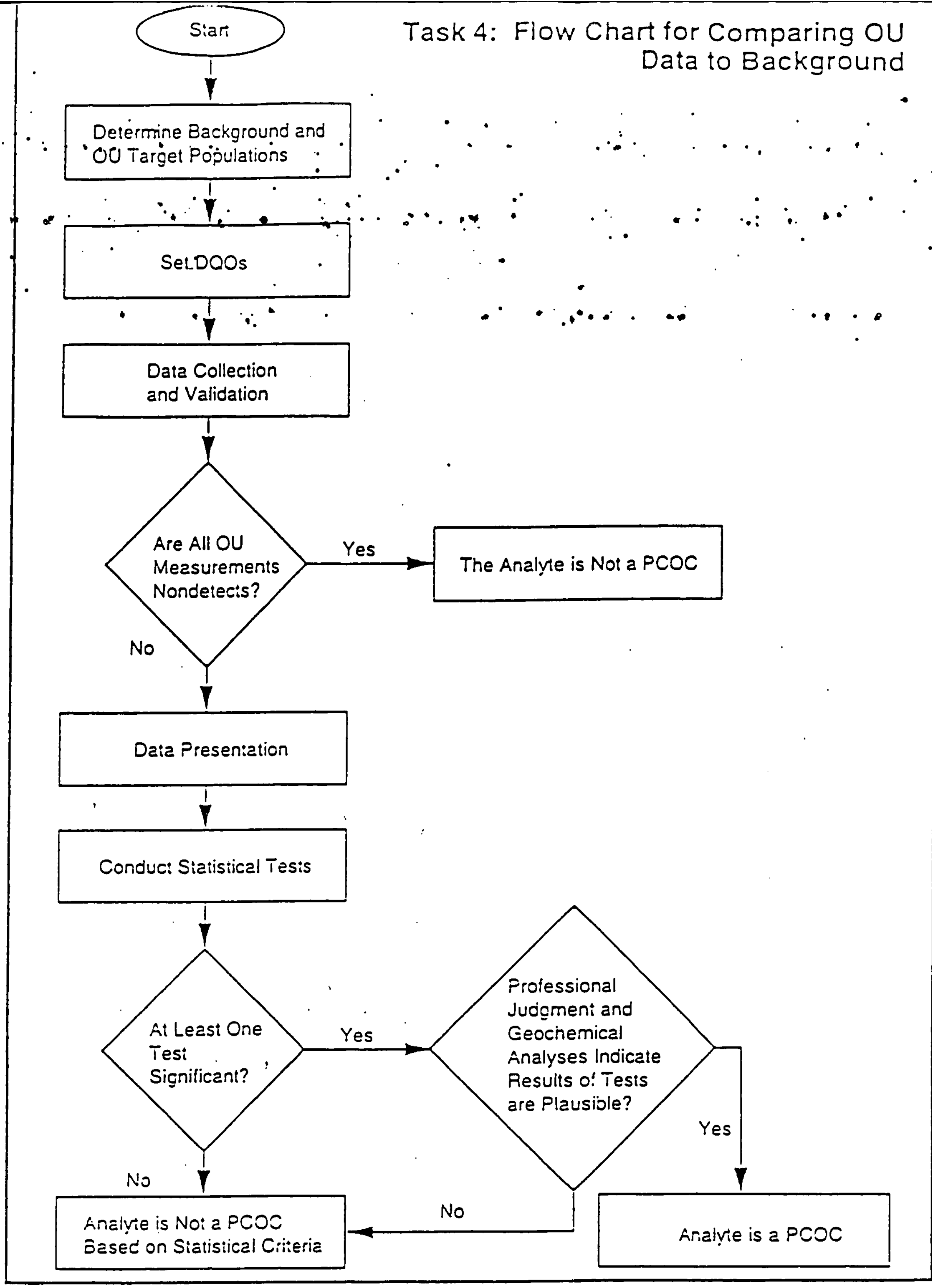
Professional Judgement

The following general guidelines will be used individually and collectively, in conjunction with the above comparison and statistical "tools" to ascertain if a reported analytical detection(s) constitutes contamination at the OU. When professional judgement is applied, documented and defensible evidence will be furnished, and DOE will bear the "burden of proof".

- **Spatial distribution** of analytes above background are or are not indicative of contamination due to waste-related activities at the OU. Spatial plots, interpreted in a source-to-receptor conceptual model, in addition to compound-specific mobility considerations, generally assist in interpretation of inconclusive results.

- **Temporal distribution** of analyte concentrations at a station indicates the "high" value(s) is(are) outlier(s). Time-series plots at wells or surface-water locations can generally be used to link apparently insignificant **outlier** reports to seasonal or hydrological phenomena, and vice versa.

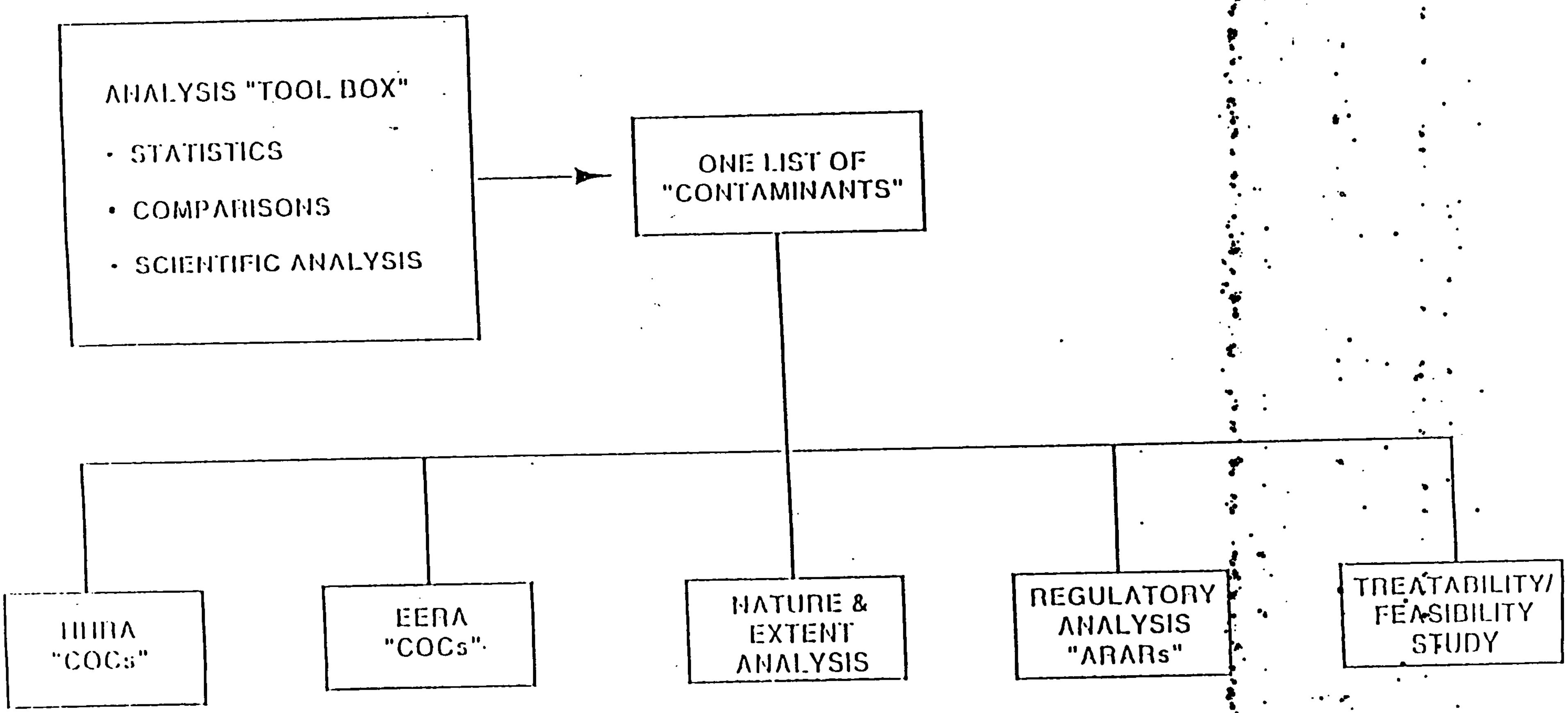
- Other associated analytes are determined not to be contaminants in the sample or at the station. Then this may be added to cumulative evidence ("burden of proof") that the analyte in question is not a potential contaminant of concern. **Pattern-recognition concepts** are useful in identifying anomalies as well as confirming "fingerprint" associations.

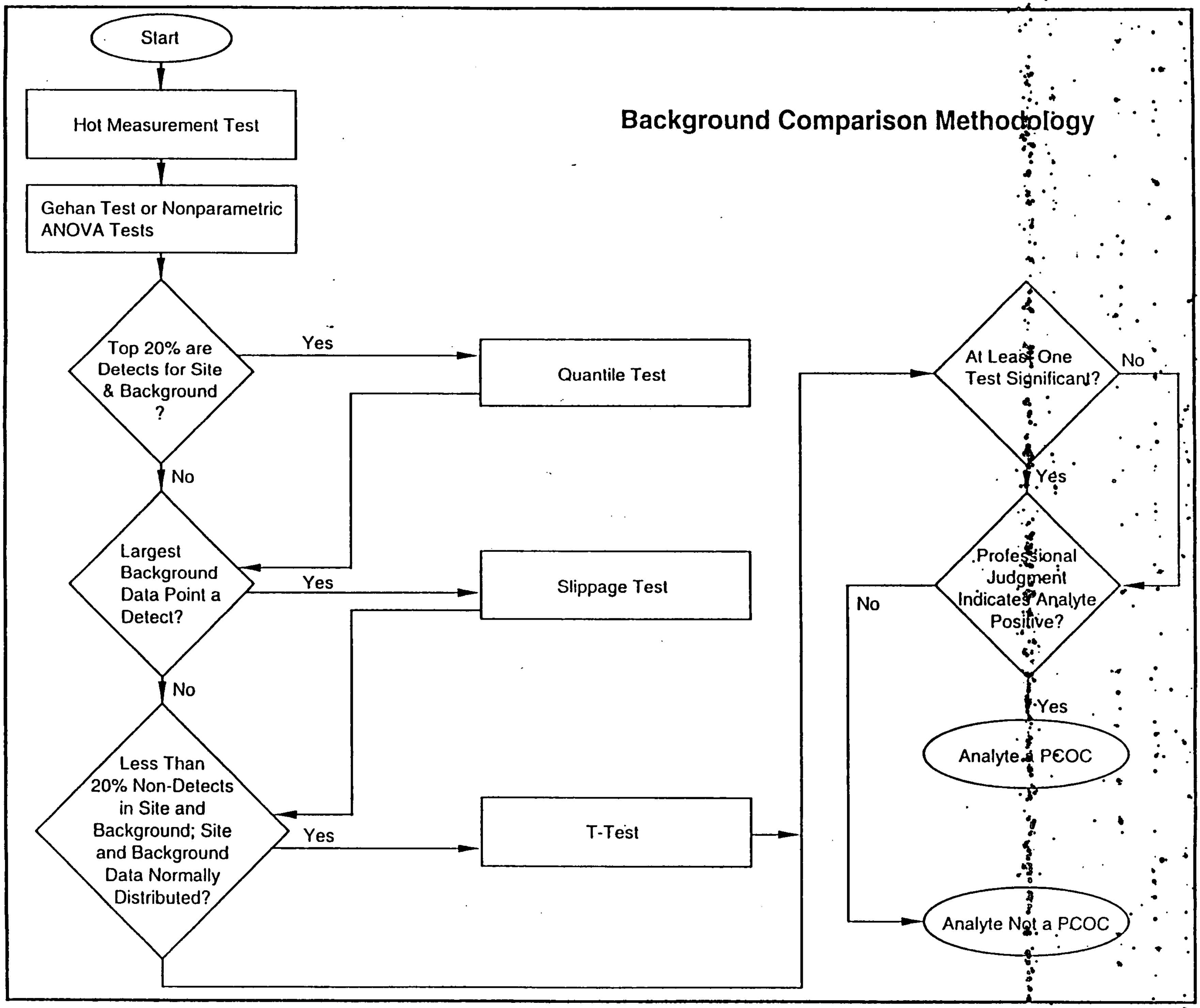

Start
Task 4: Flow Chart for Comparing OU Data to Background
Determine Background and OU Target Populations
Set DQOs
Data Collection and Validation
Are All OU Measurements Nondetects?
Yes
The Analyte is Not a PCOC
No
Data Presentation
Conduct Statistical Tests
At Least One Test Significant?
Yes
Professional Judgment and Geochemical Analyses Indicate Results of Tests are Plausible?
Yes
No
No
Analyte is Not a PCOC Based on Statistical Criteria
Analyte is a PCOC

33

31/65

# GENERAL APPROACH TO DETERMINING "CONTAMINANTS"




Background Comparison Methodology
Start
Hot Measurement Test
Gehan Test or Nonparametric ANOVA Tests
Top 20% are Detects for Site & Background ?
Yes
Quantile Test
No
Largest Background Data Point a Detect?
Yes
Slippage Test
No
Less Than 20% Non-Detects in Site and Background; Site and Background Data Normally Distributed?
Yes
T-Test
At Least One Test Significant?
No
Yes
Professional Judgment Indicates Analyte Positive?
No
Yes
Analyte a PCOC
Analyte Not a PCOC

35

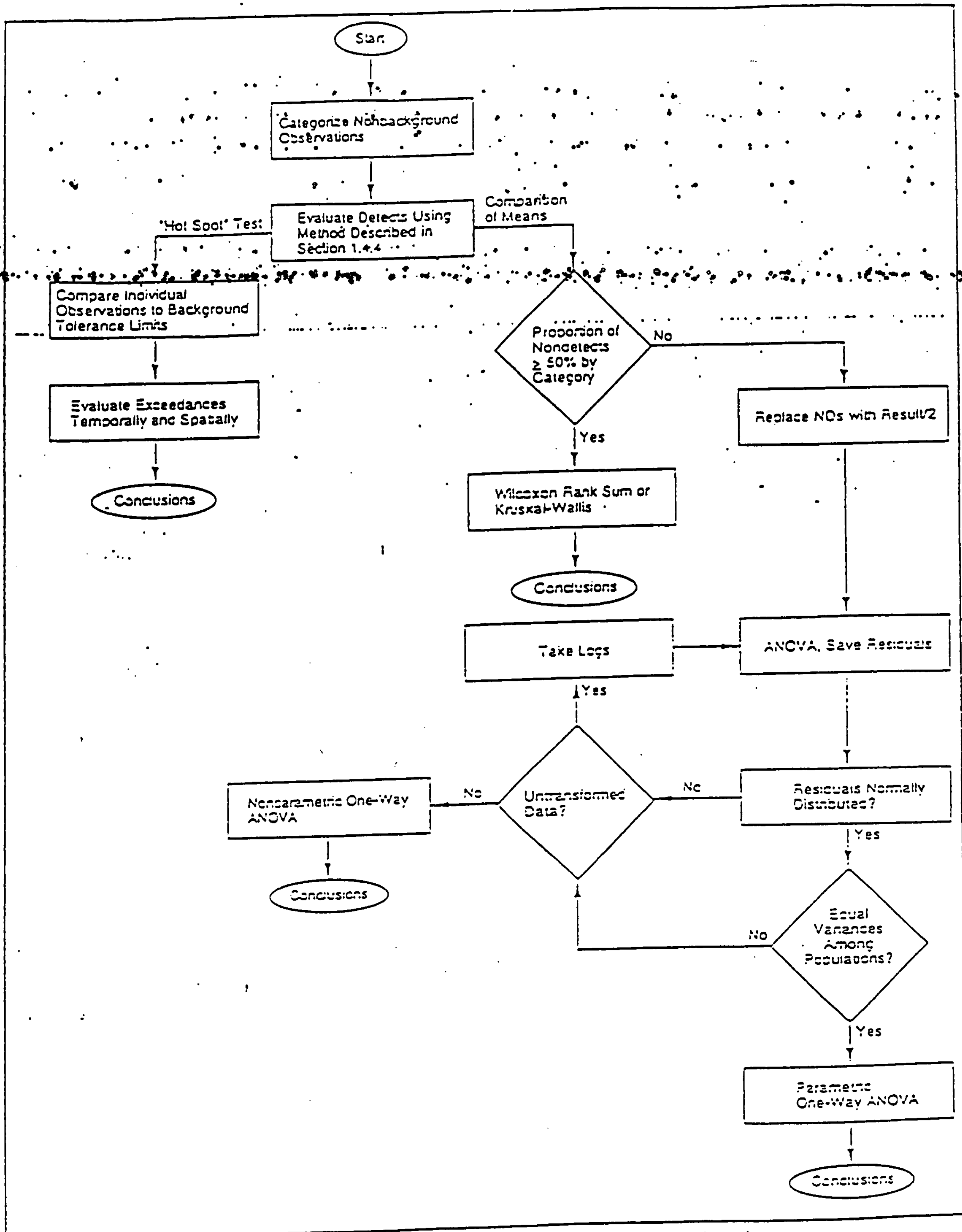



*Figure 1-2 Selection of Statistical Method for Comparison of Background and Nonbackground Populations*

36/65

Table C-1. Groundwater UTLs by geologic unit for dissolved metals.

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER; DISSOLVED METALS

| ANALYTE | GEOLOGIC UNIT | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|---|
| ALUMINUM | COL | 35 | 71.43 | 59.18 | 49.50 | 224.21 | UG/L |
| ANTIMONY | COL | 33 | 33.33 | 14.84 | 9.50 | 46.92 | UG/L |
| BARIUM | COL | 34 | 79.41 | 77.05 | 39.03 | 207.99 | UG/L |
| CADMIUM | COL | 34 | 23.53 | 1.97 | 1.67 | 7.57 | UG/L |
| CALCIUM | COL | 35 | 100.00 | 96,314.29 | 34,355.90 | 210,868.89 | UG/L |
| CHROMIUM | COL | 32 | 28.12 | 5.87 | 5.93 | 26.03 | UG/L |
| COPPER | COL | 33 | 36.36 | 5.08 | 4.20 | 19.27 | UG/L |
| IRON | COL | 34 | 61.76 | 46.38 | 79.70 | 313.70 | UG/L |
| LITHIUM | COL | 34 | 88.24 | 122.77 | 84.53 | 406.30 | UG/L |
| MAGNESIUM | COL | 34 | 100.00 | 20,479.41 | 10,610.71 | 56,070.91 | UG/L |
| MANGANESE | COL | 35 | 74.29 | 32.10 | 38.69 | 161.12 | UG/L |
| MOLYBDENUM | COL | 33 | 42.42 | 19.35 | 32.15 | 127.87 | UG/L |
| POTASSIUM | COL | 33 | 84.85 | 2,086.36 | 1,903.98 | 8,513.03 | UG/L |
| SELENIUM | COL | 32 | 62.50 | 17.40 | 42.89 | 163.12 | UG/L |
| SILVER | COL | 31 | 25.81 | 3.22 | 2.81 | 12.84 | UG/L |
| SODIUM | COL | 35 | 100.00 | 98,454.29 | 64,522.31 | 313,594.26 | UG/L |
| STRONTIUM | COL | 34 | 97.06 | 701.88 | 374.80 | 1,959.08 | UG/L |
| TIN | COL | 31 | 41.94 | 44.01 | 62.59 | 258.16 | UG/L |
| VANADIUM | COL | 32 | 65.62 | 8.17 | 7.85 | 34.84 | UG/L |
| ZINC | COL | 35 | 74.29 | 11.30 | 10.64 | 46.78 | UG/L |
| ALUMINUM | RFA | 104 | 75.00 | 68.23 | 125.93 | 361.64 | UG/L |
| ANTIMONY | RFA | 113 | 49.56 | 18.37 | 12.98 | 48.61 | UG/L |
| BARIUM | RFA | 114 | 83.33 | 72.32 | 24.50 | 129.39 | UG/L |
| CADMIUM | RFA | 107 | 22.43 | 1.66 | 1.13 | 4.29 | UG/L |
| CALCIUM | RFA | 113 | 100.00 | 37,655.53 | 18,707.96 | 81,245.08 | UG/L |
| CHROMIUM | RFA | 113 | 41.59 | 4.86 | 3.33 | 12.63 | UG/L |
| COPPER | RFA | 112 | 43.75 | 4.79 | 4.13 | 14.40 | UG/L |
| IRON | RFA | 113 | 76.99 | 70.28 | 157.23 | 436.62 | UG/L |
| LEAD | RFA | 111 | 24.32 | 1.40 | 3.01 | 8.41 | UG/L |
| LITHIUM | RFA | 109 | 68.81 | 12.68 | 17.36 | 53.12 | UG/L |
| MAGNESIUM | RFA | 112 | 91.96 | 4,266.21 | 1,369.27 | 7,456.60 | UG/L |
| MANGANESE | RFA | 114 | 52.63 | 6.17 | 15.04 | 41.21 | UG/L |
| MOLYBDENUM | RFA | 106 | 35.85 | 19.37 | 34.13 | 98.88 | UG/L |
| NICKEL | RFA | 106 | 36.79 | 7.66 | 7.65 | 25.49 | UG/L |
| POTASSIUM | RFA | 110 | 79.09 | 925.94 | 705.81 | 2,570.48 | UG/L |
| SILVER | RFA | 105 | 28.57 | 2.73 | 1.88 | 7.11 | UG/L |
| SODIUM | RFA | 112 | 98.21 | 7,602.21 | 1,740.42 | 11,657.40 | UG/L |
| STRONTIUM | RFA | 112 | 86.61 | 132.73 | 91.06 | 344.89 | UG/L |
| THALLIUM | RFA | 92 | 21.74 | 1.68 | 1.64 | 5.50 | UG/L |
| TIN | RFA | 100 | 41.00 | 29.72 | 34.02 | 108.98 | UG/L |
| VANADIUM | RFA | 111 | 62.16 | 8.36 | 9.95 | 31.54 | UG/L |
| ZINC | RFA | 113 | 79.65 | 15.69 | 19.83 | 61.88 | UG/L |



37

Table C-2. Groundwater UTLs by geologic unit for total metals.

## UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, TOTAL METALS

| ANALYTE | GEOLOGIC UNIT | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99/99 UTL | UNITS |
|---|---|---|---|---|---|---|---|
| ALUMINUM | COL | 19 | 100.00 | 745.11 | 789.02 | 3,816.32 | UG/L |
| ANTIMONY | COL | 20 | 30.00 | 17.74 | 9.52 | 54.22 | UG/L |
| ARSENIC | COL | 20 | 40.00 | 1.83 | 1.65 | 8.24 | UG/L |
| BARIUM | COL | 20 | 85.00 | 90.87 | 66.40 | 345.29 | UG/L |
| CADMIUM | COL | 20 | 25.00 | 1.97 | 1.74 | 8.64 | UG/L |
| CALCIUM | COL | 20 | 100.00 | 99,540.00 | 37,654.79 | 243,816.53 | UG/L |
| CHROMIUM | COL | 18 | 22.22 | 4.59 | 4.36 | 21.88 | UG/L |
| COPPER | COL | 20 | 65.00 | 9.29 | 11.81 | 54.54 | UG/L |
| IRON | COL | 19 | 100.00 | 665.11 | 679.22 | 3,308.92 | UG/L |
| LEAD | COL | 18 | 38.89 | 2.28 | 4.27 | 19.18 | UG/L |
| LITHIUM | COL | 20 | 85.00 | 117.94 | 86.49 | 449.35 | UG/L |
| MAGNESIUM | COL | 20 | 100.00 | 21,320.00 | 11,477.51 | 65,296.75 | UG/L |
| MANGANESE | COL | 20 | 95.00 | 57.48 | 126.39 | 541.73 | UG/L |
| MOLYBDENUM | COL | 20 | 40.00 | 23.88 | 39.19 | 174.05 | UG/L |
| NICKEL | COL | 18 | 33.33 | 7.25 | 6.31 | 32.26 | UG/L |
| POTASSIUM | COL | 20 | 75.00 | 2,013.25 | 1,893.58 | 9,268.62 | UG/L |
| SELENIUM | COL | 18 | 66.67 | 15.04 | 47.11 | 201.61 | UG/L |
| SILICON | COL | 12 | 100.00 | 8,600.75 | 2,462.31 | 20,008.64 | UG/L |
| SODIUM | COL | 20 | 100.00 | 101,010.00 | 68,738.74 | 364,386.48 | UG/L |
| STRONTIUM | COL | 20 | 100.00 | 705.85 | 379.49 | 2,159.90 | UG/L |
| THALLIUM | COL | 20 | 35.00 | 1.68 | 1.76 | 8.43 | UG/L |
| TIN | COL | 20 | 40.00 | 35.35 | 34.62 | 167.99 | UG/L |
| VANADIUM | COL | 20 | 75.00 | 16.82 | 27.37 | 121.70 | UG/L |
| ZINC | COL | 20 | 95.00 | 31.55 | 36.14 | 170.01 | UG/L |
| ALUMINUM | RFA | 66 | 93.94 | 3,844.45 | 5,057.31 | 19,223.71 | UG/L |
| ANTIMONY | RFA | 63 | 42.86 | 21.40 | 15.61 | 68.88 | UG/L |
| ARSENIC | RFA | 61 | 27.87 | 2.07 | 1.76 | 7.43 | UG/L |
| BARIUM | RFA | 66 | 78.79 | 96.13 | 36.76 | 207.92 | UG/L |
| CALCIUM | RFA | 67 | 100.00 | 38,690.30 | 17,954.04 | 93,288.54 | UG/L |
| CESIUM | RFA | 65 | 23.08 | 150.64 | 202.63 | 766.84 | UG/L |
| CHROMIUM | RFA | 64 | 56.25 | 8.21 | 7.49 | 30.99 | UG/L |
| COBALT | RFA | 66 | 21.21 | 8.46 | 10.30 | 39.78 | UG/L |
| COPPER | RFA | 66 | 77.27 | 12.25 | 13.56 | 53.48 | UG/L |
| IRON | RFA | 66 | 98.48 | 4,262.08 | 5,960.89 | 22,389.15 | UG/L |
| LEAD | RFA | 63 | 71.43 | 3.64 | 3.95 | 15.64 | UG/L |
| LITHIUM | RFA | 67 | 76.12 | 17.15 | 19.09 | 75.19 | UG/L |
| MAGNESIUM | RFA | 67 | 95.52 | 5,050.67 | 2,112.67 | 11,475.30 | UG/L |
| MANGANESE | RFA | 66 | 90.91 | 90.09 | 113.99 | 436.73 | UG/L |
| MOLYBDENUM | RFA | 68 | 33.82 | 24.80 | 40.38 | 147.60 | UG/L |
| NICKEL | RFA | 66 | 40.91 | 13.25 | 11.32 | 47.69 | UG/L |
| POTASSIUM | RFA | 68 | 76.47 | 1,578.46 | 1,190.52 | 5,198.84 | UG/L |
| SILICON | RFA | 37 | 100.00 | 19,033.92 | 11,446.15 | 56,777.23 | UG/L |
| SODIUM | RFA | 67 | 97.01 | 7,797.16 | 1,995.38 | 13,865.12 | UG/L |
| STRONTIUM | RFA | 64 | 78.12 | 125.27 | 39.20 | 244.47 | UG/L |
| TIN | RFA | 68 | 32.35 | 34.01 | 36.65 | 145.45 | UG/L |
| VANADIUM | RFA | 66 | 78.79 | 14.87 | 11.21 | 48.97 | UG/L |
| ZINC | RFA | 67 | 88.06 | 40.26 | 67.22 | 244.69 | UG/L |

Table C-2 (cont').

## UPPER-TOLERANCE LIMITS BY GEOLOGIC UNIT

### GROUNDWATER, TOTAL METALS (CONT)

| ANALYTE | GEOLOGIC. UNIT | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|---|
| ALUMINUM | VFA | 43 | 97.67 | 2,560.55 | 3,909.13 | 14,893.86 | UG/L |
| ANTIMONY | VFA | 41 | 81.71 | 16.54 | 9.66 | 47.64 | UG/L |
| ARSENIC | VFA | 41 | 31.71 | 1.70 | 1.57 | 6.65 | UG/L |
| BARIUM | VFA | 43 | 83.72 | 112.77 | 30.98 | 210.51 | UG/L |
| CADMIUM | VFA | 43 | 25.58 | 1.79 | 1.78 | 7.39 | UG/L |
| CALCIUM | VFA | 43 | 100.00 | 60,361.72 | 30,137.58 | 155,445.78 | UG/L |
| CESIUM | VFA | 40 | 30.00 | 142.06 | 184.65 | 741.90 | UG/L |
| CHROMIUM | VFA | 42 | 50.00 | 6.96 | 6.89 | 28.69 | UG/L |
| COBALT | VFA | 43 | 20.93 | 6.73 | 8.52 | 33.63 | UG/L |
| COPPER | VFA | 43 | 81.40 | 10.43 | 12.48 | 49.80 | UG/L |
| IRON | VFA | 43 | 100.00 | 2,732.59 | 4,579.64 | 17,181.35 | UG/L |
| LEAD | VFA | 40 | 77.50 | 3.39 | 3.26 | 13.97 | UG/L |
| LITHIUM | VFA | 43 | 81.40 | 22.51 | 18.95 | 82.29 | UG/L |
| MAGNESIUM | VFA | 43 | 97.67 | 12,865.24 | 6,410.62 | 33,090.74 | UG/L |
| MANGANESE | VFA | 43 | 95.35 | 92.38 | 104.18 | 421.07 | UG/L |
| MERCURY | VFA | 43 | 23.26 | 0.12 | 0.04 | 0.26 | UG/L |
| MOLYBDENUM | VFA | 43 | 27.91 | 18.90 | 36.26 | 133.29 | UG/L |
| NICKEL | VFA | 43 | 44.19 | 8.41 | 7.05 | 30.65 | UG/L |
| POTASSIUM | VFA | 43 | 81.40 | 1,785.13 | 913.58 | 4,667.48 | UG/L |
| SELENIUM | VFA | 42 | 42.86 | 3.42 | 7.97 | 28.55 | UG/L |
| SILICON | VFA | 23 | 100.00 | 15,831.46 | 11,777.33 | 59,186.61 | UG/L |
| SODIUM | VFA | 43 | 100.00 | 32,929.90 | 16,184.58 | 83,992.25 | UG/L |
| STRONTIUM | VFA | 43 | 95.35 | 374.14 | 206.92 | 1,026.97 | UG/L |
| THALLIUM | VFA | 43 | 27.91 | 1.47 | 1.59 | 6.49 | UG/L |
| TIN | VFA | 42 | 38.10 | 31.89 | 32.57 | 134.65 | UG/L |
| VANADIUM | VFA | 43 | 79.07 | 12.20 | 10.56 | 45.52 | UG/L |
| ZINC | VFA | 43 | 100.00 | 39.93 | 28.56 | 130.03 | UG/L |
| ALUMINUM | WCS | 19 | 89.47 | 1,326.18 | 2,630.79 | 11,566.37 | UG/L |
| ANTIMONY | WCS | 17 | 47.06 | 19.09 | 10.53 | 61.58 | UG/L |
| BARIUM | WCS | 19 | 84.21 | 113.17 | 66.05 | 370.27 | UG/L |
| CALCIUM | WCS | 19 | 100.00 | 53,731.58 | 13,527.83 | 106,387.86 | UG/L |
| CESIUM | WCS | 20 | 35.00 | 188.32 | 215.25 | 1,013.07 | UG/L |
| CHROMIUM | WCS | 19 | 36.84 | 5.40 | 4.02 | 21.06 | UG/L |
| COPPER | WCS | 19 | 57.89 | 7.15 | 4.34 | 24.03 | UG/L |
| IRON | WCS | 19 | 89.47 | 1,690.19 | 3,323.94 | 14,628.42 | UG/L |
| LEAD | WCS | 19 | 73.68 | 2.68 | 2.62 | 12.89 | UG/L |
| LITHIUM | WCS | 19 | 73.68 | 29.12 | 15.94 | 91.18 | UG/L |
| MAGNESIUM | WCS | 19 | 100.00 | 11,527.89 | 3,792.95 | 26,291.71 | UG/L |
| MANGANESE | WCS | 19 | 68.42 | 37.44 | 56.99 | 259.28 | UG/L |
| MOLYBDENUM | WCS | 19 | 42.11 | 33.49 | 44.45 | 206.49 | UG/L |
| POTASSIUM | WCS | 19 | 73.68 | 1,858.95 | 500.67 | 3,807.76 | UG/L |
| SELENIUM | WCS | 18 | 50.00 | 9.10 | 19.03 | 84.48 | UG/L |
| SILICON | WCS | 10 | 100.00 | 10,474.00 | 5,966.37 | 40,745.70 | UG/L |
| SODIUM | WCS | 19 | 100.00 | 27,557.89 | 9,531.60 | 64,659.09 | UG/L |
| STRONTIUM | WCS | 19 | 100.00 | 390.47 | 150.51 | 976.33 | UG/L |
| THALLIUM | WCS | 18 | 27.78 | 1.95 | 1.96 | 9.71 | UG/L |
| TIN | WCS | 19 | 31.58 | 36.28 | 39.56 | 190.26 | UG/L |
| VANADIUM | WCS | 19 | 68.42 | 10.57 | 9.20 | 46.39 | UG/L |
| ZINC | WCS | 19 | 84.21 | 25.91 | 17.93 | 95.69 | UG/L |



39

Table C-2 (cont').

## UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

### GROUNDWATER, TOTAL METALS (CONT')

| ANALYTE | GEOLOGIC UNIT | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99/99 UTL | UNITS |
|---|---|---|---|---|---|---|---|
| ALUMINUM | KAR | 37 | 91.89 | 1,791.87 | 2,773.43 | 10,937.17 | UG/L |
| ANTIMONY | KAR | 35 | 31.43 | 15.62 | 10.40 | 50.28 | UG/L |
| ARSENIC | KAR | 35 | 54.29 | 2.76 | 2.02 | 9.51 | UG/L |
| BARIUM | KAR | 36 | 86.11 | 113.95 | 51.97 | 286.27 | UG/L |
| CALCIUM | KAR | 37 | 100.00 | 36,382.43 | 23,881.47 | 115,130.79 | UG/L |
| CESIUM | KAR | 35 | 25.71 | 131.59 | 175.16 | 715.62 | UG/L |
| CHROMIUM | KAR | 36 | 38.89 | 5.25 | 4.61 | 20.54 | UG/L |
| COPPER | KAR | 36 | 61.11 | 11.99 | 21.82 | 84.34 | UG/L |
| IRON | KAR | 37 | 94.59 | 2,239.92 | 3,697.44 | 14,432.11 | UG/L |
| LEAD | KAR | 36 | 61.11 | 3.82 | 4.29 | 18.06 | UG/L |
| LITHIUM | KAR | 37 | 86.49 | 40.69 | 29.29 | 137.26 | UG/L |
| MAGNESIUM | KAR | 37 | 94.59 | 6,679.46 | 5,030.81 | 23,268.40 | UG/L |
| MANGANESE | KAR | 37 | 86.49 | 61.87 | 125.21 | 474.75 | UG/L |
| MERCURY | KAR | 37 | 27.03 | 0.13 | 0.05 | 0.28 | UG/L |
| MOLYBDENUM | KAR | 36 | 47.22 | 18.59 | 33.45 | 129.48 | UG/L |
| NICKEL | KAR | 35 | 34.29 | 8.70 | 7.25 | 32.89 | UG/L |
| POTASSIUM | KAR | 37 | 89.19 | 2,846.38 | 1,725.69 | 8,536.77 | UG/L |
| SELENIUM | KAR | 36 | 33.33 | 1.19 | 0.63 | 3.27 | UG/L |
| SILICON | KAR | 20 | 100.00 | 9,427.50 | 6,631.12 | 34,835.00 | UG/L |
| SODIUM | KAR | 37 | 100.00 | 139,228.38 | 134,404.33 | 582,422.16 | UG/L |
| STRONTIUM | KAR | 37 | 97.30 | 399.78 | 312.58 | 1,430.50 | UG/L |
| THALLIUM | KAR | 36 | 27.78 | 1.40 | 1.50 | 6.36 | UG/L |
| TIN | KAR | 37 | 29.73 | 27.46 | 31.18 | 130.28 | UG/L |
| VANADIUM | KAR | 36 | 69.44 | 10.43 | 11.26 | 47.75 | UG/L |
| ZINC | KAR | 36 | 97.22 | 52.45 | 51.31 | 222.56 | UG/L |



40

46/6

Table C-3. Groundwater UTLs by geologic unit for dissolved radionuclides.

## UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, DISSOLVED RADIONUCLIDES

| ANALYTE | GEOLOGIC UNIT | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | UTL 99 / 99 | UNITS |
|---|---|---|---|---|---|---|---|
| CESIUM-137 | COL | 2 | 100.00 | 0.36 | 0.42 | 78.73 | pCi/L |
| GROSS ALPHA | COL | 30 | 100.00 | 43.37 | 78.79 | 312.85 | pCi/L |
| GROSS BETA | COL | 27 | 100.00 | 17.51 | 29.87 | 123.04 | pCi/L |
| RADIUM-226 | COL | 15 | 100.00 | 0.21 | 0.10 | 0.64 | pCi/L |
| STRONTIUM-89,90 | COL | 23 | 100.00 | 0.25 | 0.24 | 1.13 | pCi/L |
| TRITIUM | COL | 31 | 100.00 | 76.12 | 109.42 | 450.48 | pCi/L |
| URANIUM-233,234 | COL | 30 | 100.00 | 31.82 | 56.44 | 226.34 | pCi/L |
| URANIUM-235 | COL | 30 | 100.00 | 0.86 | 1.39 | 5.63 | pCi/L |
| URANIUM-238 | COL | 24 | 100.00 | 26.70 | 42.13 | 180.03 | pCi/L |
| CESIUM-137 | RFA | 15 | 100.00 | 0.27 | 0.29 | 1.48 | pCi/L |
| GROSS ALPHA | RFA | 82 | 100.00 | 0.59 | 0.80 | 3.02 | pCi/L |
| GROSS BETA | RFA | 76 | 100.00 | 1.66 | 1.52 | 6.28 | pCi/L |
| RADIUM-226 | RFA | 2 | 100.00 | 0.17 | 0.04 | 7.91 | pCi/L |
| RADIUM-228 | RFA | 2 | 100.00 | 2.20 | 0.42 | 80.95 | pCi/L |
| STRONTIUM-89,90 | RFA | 81 | 100.00 | 0.27 | 0.23 | 0.98 | pCi/L |
| TRITIUM | RFA | 63 | 100.00 | 163.03 | 223.01 | 841.20 | pCi/L |
| URANIUM-233,234 | RFA | 78 | 100.00 | 0.23 | 0.21 | 0.88 | pCi/L |
| URANIUM-235 | RFA | 78 | 100.00 | 0.03 | 0.07 | 0.23 | pCi/L |
| URANIUM-238 | RFA | 69 | 100.00 | 0.14 | 0.14 | 0.56 | pCi/L |
| CESIUM-137 | VFA | 17 | 100.00 | 0.58 | 0.71 | 3.43 | pCi/L |
| GROSS ALPHA | VFA | 60 | 100.00 | 2.93 | 3.17 | 12.94 | pCi/L |
| GROSS BETA | VFA | 55 | 100.00 | 3.20 | 1.69 | 8.54 | pCi/L |
| RADIUM-226 | VFA | 13 | 100.00 | 0.31 | 0.11 | 0.81 | pCi/L |
| RADIUM-228 | VFA | 4 | 100.00 | 2.08 | 0.62 | 9.76 | pCi/L |
| STRONTIUM-89,90 | VFA | 59 | 100.00 | 0.49 | 0.38 | 1.68 | pCi/L |
| TRITIUM | VFA | 42 | 100.00 | 115.00 | 137.64 | 549.26 | pCi/L |
| URANIUM-233,234 | VFA | 60 | 100.00 | 2.05 | 2.77 | 10.80 | pCi/L |
| URANIUM-235 | VFA | 60 | 100.00 | 0.08 | 0.12 | 0.47 | pCi/L |
| URANIUM-238 | VFA | 49 | 100.00 | 1.66 | 2.30 | 8.92 | pCi/L |
| CESIUM-137 | WCS | 4 | 100.00 | 0.32 | 0.20 | 2.86 | pCi/L |
| GROSS ALPHA | WCS | 41 | 100.00 | 7.70 | 5.95 | 26.47 | pCi/L |
| GROSS BETA | WCS | 38 | 100.00 | 4.85 | 3.22 | 15.41 | pCi/L |
| RADIUM-226 | WCS | 6 | 100.00 | 0.32 | 0.06 | 0.78 | pCi/L |
| STRONTIUM-89,90 | WCS | 17 | 100.00 | 0.24 | 0.24 | 1.21 | pCi/L |
| TRITIUM | WCS | 29 | 100.00 | -23.42 | 118.54 | 388.30 | pCi/L |
| URANIUM-233,234 | WCS | 39 | 100.00 | 8.59 | 21.06 | 77.33 | pCi/L |
| URANIUM-235 | WCS | 39 | 100.00 | 0.20 | 0.51 | 1.88 | pCi/L |
| URANIUM-238 | WCS | 35 | 100.00 | 3.54 | 3.19 | 14.17 | pCi/L |
| CESIUM-137 | KAR | 4 | 100.00 | 0.22 | 0.30 | 3.92 | pCi/L |
| GROSS ALPHA | KAR | 60 | 100.00 | 3.13 | 6.24 | 22.81 | pCi/L |
| GROSS BETA | KAR | 54 | 100.00 | 3.23 | 2.84 | 12.19 | pCi/L |
| RADIUM-226 | KAR | 2 | 100.00 | 1.72 | 1.78 | 331.75 | pCi/L |
| STRONTIUM-89,90 | KAR | 42 | 100.00 | 0.47 | 1.19 | 4.21 | pCi/L |
| TRITIUM | KAR | 49 | 100.00 | 56.88 | 135.94 | 485.77 | pCi/L |
| URANIUM-233,234 | KAR | 57 | 100.00 | 1.64 | 2.85 | 10.63 | pCi/L |
| URANIUM-235 | KAR | 57 | 100.00 | 0.03 | 0.06 | 0.23 | pCi/L |
| URANIUM-238 | KAR | 54 | 100.00 | 0.77 | 1.53 | 5.58 | pCi/L |



41

41/65

Table C-4. Groundwater UTLs by geologic unit for total radionuclides.

## UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, TOTAL RADIONUCLIDES

| ANALYTE | GEOLOGIC UNIT | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | UTL 99 / 99 | UNITS |
|---|---|---|---|---|---|---|---|
| AMERICIUM-241 | COL | 25 | 100.00 | 0.00 | 0.00 | 0.01 | pCi/L |
| CESIUM-137 | COL | 23 | 100.00 | 0.18 | 0.35 | 1.49 | pCi/L |
| GROSS ALPHA | COL | 6 | 100.00 | 150.35 | 142.75 | 1,197.38 | pCi/L |
| GROSS BETA | COL | 6 | 100.00 | 81.55 | 85.25 | 706.79 | pCi/L |
| PLUTONIUM-239,240 | COL | 26 | 100.00 | 0.01 | 0.01 | 0.04 | pCi/L |
| STRONTIUM-89,90 | COL | 7 | 100.00 | 0.26 | 0.11 | 0.95 | pCi/L |
| TRITIUM | COL | 17 | 100.00 | 201.15 | 193.39 | 981.82 | pCi/L |
| URANIUM-233,234 | COL | 8 | 100.00 | 58.74 | 66.80 | 446.99 | pCi/L |
| URANIUM-235 | COL | 8 | 100.00 | 2.14 | 2.39 | 16.03 | pCi/L |
| URANIUM-238 | COL | 6 | 100.00 | 36.04 | 46.48 | 376.92 | pCi/L |
| AMERICIUM-241 | RFA | 82 | 100.00 | 0.01 | 0.01 | 0.03 | pCi/L |
| CESIUM-137 | RFA | 75 | 100.00 | 0.08 | 0.33 | 1.09 | pCi/L |
| GROSS ALPHA | RFA | 5 | 100.00 | 1.89 | 1.28 | 13.30 | pCi/L |
| GROSS BETA | RFA | 5 | 100.00 | 2.25 | 1.48 | 15.45 | pCi/L |
| PLUTONIUM-238 | RFA | 7 | 100.00 | 0.00 | 0.00 | 0.01 | pCi/L |
| PLUTONIUM-239,240 | RFA | 85 | 100.00 | 0.00 | 0.00 | 0.01 | pCi/L |
| STRONTIUM-89,90 | RFA | 13 | 100.00 | 0.11 | 0.21 | 1.04 | pCi/L |
| TRITIUM | RFA | 21 | 100.00 | 226.72 | 307.18 | 1,386.83 | pCi/L |
| URANIUM-233,234 | RFA | 12 | 100.00 | 0.48 | 0.45 | 2.58 | pCi/L |
| URANIUM-235 | RFA | 12 | 100.00 | 0.12 | 0.20 | 1.05 | pCi/L |
| URANIUM-238 | RFA | 11 | 100.00 | 0.40 | 0.50 | 2.83 | pCi/L |
| AMERICIUM-241 | VFA | 56 | 100.00 | 0.01 | 0.01 | 0.05 | pCi/L |
| CESIUM-137 | VFA | 44 | 100.00 | 0.10 | 0.30 | 1.05 | pCi/L |
| GROSS ALPHA | VFA | 7 | 100.00 | 3.66 | 2.06 | 16.84 | pCi/L |
| GROSS BETA | VFA | 7 | 100.00 | 4.54 | 2.83 | 22.66 | pCi/L |
| PLUTONIUM-238 | VFA | 6 | 100.00 | 0.01 | 0.01 | 0.09 | pCi/L |
| PLUTONIUM-239,240 | VFA | 62 | 100.00 | 0.01 | 0.04 | 0.12 | pCi/L |
| STRONTIUM-89,90 | VFA | 8 | 100.00 | 0.43 | 0.37 | 2.56 | pCi/L |
| TRITIUM | VFA | 27 | 100.00 | 142.98 | 180.32 | 779.97 | pCi/L |
| URANIUM-233,234 | VFA | 7 | 100.00 | 1.58 | 1.00 | 8.01 | pCi/L |
| URANIUM-235 | VFA | 7 | 100.00 | 0.10 | 0.10 | 0.75 | pCi/L |
| URANIUM-238 | VFA | 2 | 100.00 | 1.23 | 1.20 | 223.18 | pCi/L |



42

43/65

Table C-5. Groundwater UTLs by geologic unit for water-quality parameters.

## UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, WATER-QUALITY PARAMETERS

| ANALYTE | GEOLOGIC UNIT | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|---|
| BICARBONATE | COL | 52 | 100.00 | 393,871.94 | 175,851.17 | 948,682.39 | UG/L |
| CHLORIDE | COL | 42 | 100.00 | 18,114.29 | 10,104.20 | 49,993.05 | UG/L |
| FLUORIDE | COL | 51 | 100.00 | 1,053.73 | 536.87 | 2,747.56 | UG/L |
| NITRATE/NITRITE | COL | 56 | 64.29 | 1,683.75 | 3,700.64 | 13,359.28 | UG/L |
| ORTHOPHOSPHATE | COL | 27 | 48.15 | 11.93 | 7.48 | 38.34 | UG/L |
| PHOSPHORUS | COL | 10 | 40.00 | 30.50 | 29.86 | 181.98 | UG/L |
| SILICA | COL | 44 | 100.00 | 12,037.35 | 6,549.60 | 32,701.34 | UG/L |
| SULFATE | COL | 48 | 100.00 | 215,566.67 | 264,980.47 | 1,051,580.04 | UG/L |
| TOTAL DISSOLVED SOLIDS | COL | 52 | 100.00 | 687,230.77 | 409,401.70 | 1,978,893.12 | UG/L |
| TOTAL SUSPENDED SOLIDS | COL | 52 | 67.31 | 18,038.46 | 24,207.00 | 94,411.55 | UG/L |
| BICARBONATE | RFA | 114 | 100.00 | 114,859.08 | 56,766.87 | 247,125.88 | UG/L |
| CHLORIDE | RFA | 95 | 91.58 | 8,707.47 | 13,538.26 | 40,251.63 | UG/L |
| FLUORIDE | RFA | 108 | 96.30 | 306.39 | 90.85 | 518.06 | UG/L |
| NITRATE/NITRITE | RFA | 115 | 97.39 | 1,448.26 | 765.26 | 3,231.31 | UG/L |
| NITRITE | RFA | 23 | 43.48 | 33.13 | 53.44 | 229.87 | UG/L |
| ORTHOPHOSPHATE | RFA | 81 | 56.79 | 14.44 | 12.92 | 53.73 | UG/L |
| PHOSPHORUS | RFA | 22 | 68.18 | 44.27 | 49.43 | 228.50 | UG/L |
| SILICA | RFA | 105 | 100.00 | 15,873.61 | 8,274.40 | 35,152.97 | UG/L |
| SULFATE | RFA | 103 | 99.03 | 22,384.47 | 19,440.47 | 67,680.75 | UG/L |
| TOTAL DISSOLVED SOLIDS | RFA | 115 | 100.00 | 189,817.39 | 94,386.90 | 409,738.87 | UG/L |
| TOTAL SUSPENDED SOLIDS | RFA | 111 | 86.49 | 182,684.68 | 334,207.01 | 961,387.02 | UG/L |
| BICARBONATE | VFA | 78 | 100.00 | 242,462.09 | 116,731.17 | 597,441.57 | UG/L |
| CHLORIDE | VFA | 67 | 97.01 | 16,061.19 | 12,727.88 | 54,766.69 | UG/L |
| CYANIDE | VFA | 21 | 28.57 | 9.39 | 5.70 | 30.92 | UG/L |
| FLUORIDE | VFA | 76 | 97.37 | 505.27 | 186.31 | 1,071.82 | UG/L |
| NITRATE/NITRITE | VFA | 72 | 65.28 | 202.08 | 257.28 | 984.46 | UG/L |
| NITRITE | VFA | 12 | 25.00 | 19.17 | 15.05 | 88.90 | UG/L |
| ORTHOPHOSPHATE | VFA | 54 | 55.56 | 17.82 | 27.04 | 103.13 | UG/L |
| PHOSPHORUS | VFA | 15 | 46.67 | 44.67 | 42.49 | 224.10 | UG/L |
| SILICA | VFA | 76 | 100.00 | 15,164.53 | 8,599.63 | 41,315.99 | UG/L |
| SULFATE | VFA | 69 | 100.00 | 54,486.96 | 74,995.26 | 282,547.55 | UG/L |
| TOTAL DISSOLVED SOLIDS | VFA | 76 | 100.00 | 334,744.54 | 167,754.49 | 844,885.94 | UG/L |
| TOTAL SUSPENDED SOLIDS | VFA | 72 | 88.89 | 90,727.64 | 141,259.37 | 520,297.38 | UG/L |

Table C-5 (cont').

## UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

### GROUNDWATER, WATER-QUALITY PARAMETERS (CONT')

| ANALYTE | GEOLOGIC UNIT | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|---|
| BICARBONATE | WCS | 67 | 100.00 | 255,472.87 | 134,489.69 | 664,456.02 | UG/L |
| CHLORIDE | WCS | 53 | 83.02 | 9,094.34 | 11,230.61 | 44,526.93 | UG/L |
| CYANIDE | WCS | 7 | 28.57 | 10.00 | 7.07 | 55.34 | UG/L |
| FLUORIDE | WCS | 65 | 98.46 | 893.69 | 595.09 | 2,703.37 | UG/L |
| NITRATE/NITRITE | WCS | 62 | 87.10 | 715.40 | 1,067.15 | 3,960.61 | UG/L |
| NITRITE | WCS | 11 | 63.64 | 28.82 | 27.52 | 161.71 | UG/L |
| ORTHOPHOSPHATE | WCS | 29 | 44.83 | 14.48 | 11.52 | 54.50 | UG/L |
| PHOSPHORUS | WCS | 9 | 66.67 | 28.89 | 31.30 | 197.58 | UG/L |
| SILICA | WCS | 49 | 100.00 | 10,404.94 | 6,489.24 | 30,878.48 | UG/L |
| SULFATE | WCS | 58 | 100.00 | 131,008.62 | 241,197.17 | 891,985.69 | UG/L |
| TOTAL DISSOLVED SOLIDS | WCS | 67 | 100.00 | 405,940.30 | 375,873.93 | 1,548,972.91 | UG/L |
| TOTAL SUSPENDED SOLIDS | WCS | 66 | 69.70 | 187,939.39 | 787,142.93 | 2,581,641.05 | UG/L |
| ALKALINITY AS CACO3 | KAR | 3 | 100.00 | 305,166.67 | 160,234.46 | 4,134,059.44 | UG/L |
| BICARBONATE | KAR | 93 | 100.00 | 233,546.17 | 102,980.99 | 473,491.87 | UG/L |
| CARBONATE | KAR | 92 | 28.26 | 3,318.77 | 4,245.24 | 13,210.17 | UG/L |
| CHLORIDE | KAR | 79 | 96.20 | 100,205.95 | 128,066.02 | 489,654.73 | UG/L |
| FLUORIDE | KAR | 92 | 97.83 | 949.35 | 465.34 | 2,033.58 | UG/L |
| NITRATE/NITRITE | KAR | 90 | 78.89 | 861.22 | 945.96 | 3,737.87 | UG/L |
| NITRITE | KAR | 16 | 56.25 | 190.62 | 295.19 | 1,407.78 | UG/L |
| ORTHOPHOSPHATE | KAR | 54 | 61.11 | 18.46 | 10.16 | 50.52 | UG/L |
| PHOSPHORUS | KAR | 14 | 64.29 | 173.57 | 264.99 | 1,322.89 | UG/L |
| SILICA | KAR | 83 | 100.00 | 8,077.25 | 5,808.92 | 25,742.17 | UG/L |
| SULFATE | KAR | 82 | 95.12 | 123,943.90 | 250,872.10 | 886,845.95 | UG/L |
| TOTAL DISSOLVED SOLIDS | KAR | 94 | 100.00 | 545,138.30 | 445,290.59 | 1,582,665.38 | UG/L |
| TOTAL SOLIDS | KAR | 5 | 80.00 | 318,240.00 | 356,657.98 | 3,506,414.55 | UG/L |
| TOTAL SUSPENDED SOLIDS | KAR | 88 | 77.27 | 403,085.23 | 727,972.80 | 2,616,850.51 | UG/L |



44

44/65

Table C-6. Groundwater UTLs by flow-system for dissolved metals.

## UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GROUNDWATER, DISSOLVED METALS

| ANALYTE | FLOW-SYSTEM | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|---|
| ALUMINUM | LOWER | 66 | 78.79 | 48.81 | 44.02 | 182.67 | UG/L |
| ANTIMONY | LOWER | 63 | 44.44 | 15.50 | 9.17 | 43.37 | UG/L |
| ARSENIC | LOWER | 59 | 49.15 | 2.41 | 1.70 | 7.77 | UG/L |
| BARIUM | LOWER | 66 | 86.36 | 84.18 | 21.79 | 150.44 | UG/L |
| CADMIUM | LOWER | 62 | 22.58 | 1.76 | 1.33 | 5.80 | UG/L |
| CALCIUM | LOWER | 67 | 100.00 | 34,535.82 | 23,552.79 | 106,159.84 | UG/L |
| CESIUM | LOWER | 54 | 29.63 | 160.88 | 179.94 | 728.59 | UG/L |
| CHROMIUM | LOWER | 65 | 26.15 | 3.97 | 3.15 | 13.55 | UG/L |
| COPPER | LOWER | 65 | 27.69 | 4.17 | 3.83 | 15.82 | UG/L |
| IRON | LOWER | 67 | 79.10 | 33.67 | 35.32 | 141.06 | UG/L |
| LEAD | LOWER | 64 | 20.31 | 1.80 | 5.27 | 17.83 | UG/L |
| LITHIUM | LOWER | 66 | 81.82 | 38.53 | 27.84 | 123.21 | UG/L |
| MAGNESIUM | LOWER | 67 | 97.01 | 6,072.16 | 4,067.56 | 18,441.63 | UG/L |
| MANGANESE | LOWER | 67 | 71.64 | 9.29 | 7.24 | 31.31 | UG/L |
| MOLYBDENUM | LOWER | 64 | 53.13 | 16.86 | 27.01 | 99.00 | UG/L |
| NICKEL | LOWER | 65 | 23.08 | 5.81 | 6.26 | 24.86 | UG/L |
| PHOSPHORUS | LOWER | 4 | 100.00 | 174.75 | 85.65 | 1,235.68 | UG/L |
| POTASSIUM | LOWER | 67 | 89.55 | 2,731.18 | 1,612.39 | 7,634.46 | UG/L |
| SELENIUM | LOWER | 54 | 29.63 | 1.34 | 1.09 | 4.78 | UG/L |
| SILVER | LOWER | 59 | 28.81 | 2.69 | 2.01 | 9.03 | UG/L |
| SODIUM | LOWER | 67 | 100.00 | 142,012.69 | 135,521.56 | 554,133.75 | UG/L |
| STRONTIUM | LOWER | 66 | 100.00 | 383.02 | 294.27 | 1,277.90 | UG/L |
| THALLIUM | LOWER | 56 | 21.43 | 1.72 | 1.87 | 7.62 | UG/L |
| TIN | LOWER | 65 | 40.00 | 23.07 | 25.30 | 100.01 | UG/L |
| VANADIUM | LOWER | 65 | 56.92 | 6.71 | 7.60 | 29.81 | UG/L |
| ZINC | LOWER | 67 | 83.58 | 10.96 | 10.20 | 41.99 | UG/L |
| ALUMINUM | UPPER | 246 | 77.64 | 59.52 | 87.29 | 262.91 | UG/L |
| ANTIMONY | UPPER | 248 | 48.39 | 17.34 | 11.10 | 43.20 | UG/L |
| BARIUM | UPPER | 256 | 83.59 | 83.42 | 34.56 | 163.94 | UG/L |
| CADMIUM | UPPER | 240 | 22.08 | 1.73 | 1.26 | 4.66 | UG/L |
| CALCIUM | UPPER | 256 | 100.00 | 55,414.55 | 32,564.11 | 131,288.91 | UG/L |
| CESIUM | UPPER | 211 | 21.33 | 202.20 | 285.69 | 867.87 | UG/L |
| CHROMIUM | UPPER | 250 | 36.00 | 4.84 | 3.80 | 13.69 | UG/L |
| COPPER | UPPER | 248 | 39.11 | 5.01 | 4.42 | 15.32 | UG/L |
| CYANIDE | UPPER | 3 | 33.33 | 5.83 | 3.82 | 97.09 | UG/L |
| IRON | UPPER | 255 | 76.47 | 56.26 | 113.44 | 320.57 | UG/L |
| LEAD | UPPER | 251 | 23.90 | 1.59 | 4.71 | 12.57 | UG/L |
| LITHIUM | UPPER | 250 | 75.20 | 33.95 | 54.30 | 160.47 | UG/L |
| MAGNESIUM | UPPER | 253 | 95.65 | 10,038.28 | 8,309.40 | 29,399.19 | UG/L |
| MANGANESE | UPPER | 255 | 60.78 | 27.47 | 67.43 | 184.57 | UG/L |
| MOLYBDENUM | UPPER | 241 | 37.34 | 19.64 | 33.94 | 98.73 | UG/L |
| NICKEL | UPPER | 236 | 32.63 | 7.01 | 7.18 | 23.73 | UG/L |
| PHOSPHORUS | UPPER | 8 | 100.00 | 167.00 | 52.43 | 471.74 | UG/L |
| POTASSIUM | UPPER | 252 | 81.75 | 1,371.50 | 1,069.01 | 3,862.30 | UG/L |
| SELENIUM | UPPER | 219 | 31.96 | 5.58 | 19.07 | 50.02 | UG/L |
| SILVER | UPPER | 235 | 28.51 | 2.84 | 2.12 | 7.79 | UG/L |
| SODIUM | UPPER | 254 | 99.21 | 32,012.98 | 43,667.67 | 133,758.65 | UG/L |
| STRONTIUM | UPPER | 252 | 92.86 | 323.60 | 303.58 | 1,030.95 | UG/L |
| THALLIUM | UPPER | 212 | 22.17 | 1.64 | 1.63 | 5.44 | UG/L |
| TIN | UPPER | 235 | 42.98 | 30.96 | 37.34 | 117.96 | UG/L |
| VANADIUM | UPPER | 249 | 64.66 | 7.92 | 8.73 | 28.26 | UG/L |
| ZINC | UPPER | 256 | 80.47 | 14.03 | 17.87 | 55.66 | UG/L |



45

Table C-7. Groundwater UTLs by flow-system for total metals.

## UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GROUNDWATER, TOTAL METALS

| ANALYTE | FLOW-SYSTEM | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|---|
| ALUMINUM | LOWER | 37 | 91.89 | 1,791.87 | 2,773.43 | 10,937.17 | UG/L |
| ANTIMONY | LOWER | 35 | 31.43 | 15.62 | 10.40 | 50.28 | UG/L |
| ARSENIC | LOWER | 35 | 54.29 | 2.76 | 2.02 | 9.51 | UG/L |
| BARIUM | LOWER | 36 | 86.11 | 113.95 | 51.97 | 286.27 | UG/L |
| CALCIUM | LOWER | 37 | 100.00 | 36,382.43 | 23,881.47 | 115,130.79 | UG/L |
| CESIUM | LOWER | 35 | 25.71 | 131.59 | 175.16 | 715.62 | UG/L |
| CHROMIUM | LOWER | 36 | 38.89 | 5.25 | 4.61 | 20.54 | UG/L |
| COPPER | LOWER | 36 | 61.11 | 11.99 | 21.82 | 84.34 | UG/L |
| IRON | LOWER | 37 | 94.59 | 2,239.92 | 3,697.44 | 14,432.11 | UG/L |
| LEAD | LOWER | 36 | 61.11 | 3.82 | 4.29 | 18.06 | UG/L |
| LITHIUM | LOWER | 37 | 86.49 | 40.69 | 29.29 | 137.26 | UG/L |
| MAGNESIUM | LOWER | 37 | 94.59 | 6,679.46 | 5,030.81 | 23,268.40 | UG/L |
| MANGANESE | LOWER | 37 | 86.49 | 61.87 | 125.21 | 474.75 | UG/L |
| MERCURY | LOWER | 37 | 27.03 | 0.13 | 0.05 | 0.28 | UG/L |
| MOLYBDENUM | LOWER | 36 | 47.22 | 18.59 | 33.45 | 129.48 | UG/L |
| NICKEL | LOWER | 35 | 34.29 | 8.70 | 7.25 | 32.89 | UG/L |
| POTASSIUM | LOWER | 37 | 89.19 | 2,846.38 | 1,725.69 | 8,536.77 | UG/L |
| SELENIUM | LOWER | 36 | 33.33 | 1.19 | 0.63 | 3.27 | UG/L |
| SILICON | LOWER | 20 | 100.00 | 9,427.50 | 6,631.12 | 34,835.00 | UG/L |
| SODIUM | LOWER | 37 | 100.00 | 139,228.38 | 134,404.33 | 582,422.16 | UG/L |
| STRONTIUM | LOWER | 37 | 97.30 | 399.78 | 312.58 | 1,430.50 | UG/L |
| THALLIUM | LOWER | 36 | 27.78 | 1.40 | 1.50 | 6.36 | UG/L |
| TIN | LOWER | 37 | 29.73 | 27.46 | 31.18 | 130.28 | UG/L |
| VANADIUM | LOWER | 36 | 69.44 | 10.43 | 11.26 | 47.75 | UG/L |
| ZINC | LOWER | 36 | 97.22 | 52.45 | 51.31 | 222.56 | UG/L |
| ALUMINUM | UPPER | 147 | 95.24 | 2,742.80 | 4,248.73 | 12,642.33 | UG/L |
| ANTIMONY | UPPER | 141 | 38.30 | 19.19 | 12.85 | 49.14 | UG/L |
| ARSENIC | UPPER | 138 | 28.26 | 1.95 | 1.71 | 5.93 | UG/L |
| BARIUM | UPPER | 148 | 81.76 | 102.44 | 45.37 | 208.14 | UG/L |
| CALCIUM | UPPER | 149 | 100.00 | 55,030.23 | 31,667.78 | 128,816.15 | UG/L |
| CESIUM | UPPER | 142 | 24.65 | 154.42 | 198.79 | 617.60 | UG/L |
| CHROMIUM | UPPER | 143 | 47.55 | 7.01 | 6.68 | 22.58 | UG/L |
| COPPER | UPPER | 148 | 74.32 | 10.67 | 12.21 | 39.12 | UG/L |
| IRON | UPPER | 147 | 97.96 | 3,017.34 | 4,994.50 | 14,654.53 | UG/L |
| LEAD | UPPER | 140 | 69.29 | 3.26 | 3.64 | 11.75 | UG/L |
| LITHIUM | UPPER | 149 | 78.52 | 33.75 | 48.76 | 147.37 | UG/L |
| MAGNESIUM | UPPER | 149 | 97.32 | 10,315.64 | 7,956.43 | 28,854.11 | UG/L |
| MANGANESE | UPPER | 148 | 89.86 | 79.59 | 108.18 | 331.64 | UG/L |
| MERCURY | UPPER | 148 | 20.27 | 0.12 | 0.04 | 0.22 | UG/L |
| MOLYBDENUM | UPPER | 150 | 34.00 | 24.09 | 39.47 | 116.04 | UG/L |
| NICKEL | UPPER | 145 | 37.24 | 10.58 | 9.49 | 32.68 | UG/L |
| POTASSIUM | UPPER | 150 | 77.33 | 1,731.21 | 1,176.59 | 4,472.65 | UG/L |
| SELENIUM | UPPER | 144 | 30.56 | 4.57 | 18.64 | 47.99 | UG/L |
| SILICON | UPPER | 82 | 100.00 | 15,564.97 | 10,797.33 | 48,399.65 | UG/L |
| SODIUM | UPPER | 149 | 98.66 | 30,081.85 | 40,019.71 | 123,327.78 | UG/L |
| STRONTIUM | UPPER | 146 | 89.04 | 312.61 | 271.09 | 944.25 | UG/L |
| THALLIUM | UPPER | 146 | 23.97 | 1.67 | 1.76 | 5.77 | UG/L |
| TIN | UPPER | 149 | 34.90 | 33.88 | 35.33 | 116.20 | UG/L |
| VANADIUM | UPPER | 148 | 77.03 | 13.81 | 14.09 | 46.64 | UG/L |
| ZINC | UPPER | 149 | 91.95 | 37.16 | 49.80 | 153.21 | UG/L |

Table C-8. Groundwater UTLs by flow-system for dissolved radionuclides.

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GROUNDWATER, DISSOLVED RADIONUCLIDES

| ANALYTE | FLOW-SYSTEM | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | UTL 99 / 99 | UNITS |
|---|---|---|---|---|---|---|---|
| CESIUM-137 | LOWER | 4 | 100.00 | 0.22 | 0.30 | 3.92 | pCi/L |
| GROSS ALPHA | LOWER | 60 | 100.00 | 3.13 | 6.24 | 22.81 | pCi/L |
| GROSS BETA | LOWER | 54 | 100.00 | 3.23 | 2.84 | 12.19 | pCi/L |
| RADIUM-226 | LOWER | 2 | 100.00 | 1.72 | 1.78 | 331.75 | pCi/L |
| STRONTIUM-89,90 | LOWER | 42 | 100.00 | 0.47 | 1.19 | 4.21 | pCi/L |
| TRITIUM | LOWER | 49 | 100.00 | 56.88 | 135.94 | 485.77 | pCi/L |
| URANIUM-233,234 | LOWER | 57 | 100.00 | 1.64 | 2.85 | 10.63 | pCi/L |
| URANIUM-235 | LOWER | 57 | 100.00 | 0.03 | 0.06 | 0.23 | pCi/L |
| URANIUM-238 | LOWER | 54 | 100.00 | 0.77 | 1.53 | 5.58 | pCi/L |
| AMERICIUM-241 | UPPER | 2 | 100.00 | 0.01 | 0.01 | 2.11 | pCi/L |
| CESIUM-137 | UPPER | 38 | 100.00 | 0.42 | 0.53 | 2.14 | pCi/L |
| GROSS ALPHA | UPPER | 213 | 100.00 | 8.35 | 32.32 | 93.86 | pCi/L |
| GROSS BETA | UPPER | 196 | 100.00 | 4.89 | 12.23 | 37.25 | pCi/L |
| RADIUM-226 | UPPER | 36 | 100.00 | 0.26 | 0.11 | 0.63 | pCi/L |
| RADIUM-228 | UPPER | 6 | 100.00 | 2.12 | 0.52 | 5.94 | pCi/L |
| STRONTIUM-89,90 | UPPER | 180 | 100.00 | 0.34 | 0.31 | 1.05 | pCi/L |
| TRITIUM | UPPER | 165 | 100.00 | 101.70 | 180.30 | 578.79 | pCi/L |
| URANIUM-233,234 | UPPER | 207 | 100.00 | 6.91 | 25.44 | 74.22 | pCi/L |
| URANIUM-235 | UPPER | 207 | 100.00 | 0.20 | 0.64 | 1.88 | pCi/L |
| URANIUM-238 | UPPER | 177 | 100.00 | 4.83 | 17.67 | 51.60 | pCi/L |

Table C-9. Groundwater UTLs by flow-system for total radionuclides.

GROUNDWATER

TOTAL RADIONUCLIDES

| ANALYTE | FLOW-SYSTEM | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | UTL 99 / 99 | |
|---|---|---|---|---|---|---|---|
| AMERICIUM-241 | LOWER | 43 | 100.00 | 0.01 | 0.02 | 0.07 | pCi/L |
| CESIUM-137 | LOWER | 39 | 100.00 | 0.00 | 0.29 | 0.96 | pCi/L |
| GROSS ALPHA | LOWER | 6 | 100.00 | 11.08 | 16.63 | 133.08 | pCi/L |
| GROSS BETA | LOWER | 6 | 100.00 | 12.01 | 13.45 | 110.67 | pCi/L |
| PLUTONIUM-238 | LOWER | 5 | 100.00 | 0.01 | 0.01 | 0.14 | pCi/L |
| PLUTONIUM-239,240 | LOWER | 48 | 100.00 | 0.00 | 0.01 | 0.02 | pCi/L |
| RADIUM-226 | LOWER | 3 | 100.00 | 0.59 | 0.45 | 11.30 | pCi/L |
| STRONTIUM-89,90 | LOWER | 4 | 100.00 | 0.10 | 0.26 | 3.34 | pCi/L |
| TRITIUM | LOWER | 16 | 100.00 | 62.93 | 367.23 | 1,577.10 | pCi/L |
| URANIUM-233,234 | LOWER | 4 | 100.00 | 0.77 | 0.57 | 7.79 | pCi/L |
| URANIUM-235 | LOWER | 4 | 100.00 | 0.03 | 0.02 | 0.27 | pCi/L |
| URANIUM-238 | LOWER | 2 | 100.00 | 0.35 | 0.26 | 48.13 | pCi/L |
| AMERICIUM-241 | UPPER | 183 | 100.00 | 0.01 | 0.01 | 0.03 | pCi/L |
| CESIUM-137 | UPPER | 156 | 100.00 | 0.12 | 0.33 | 1.00 | pCi/L |
| GROSS ALPHA | UPPER | 23 | 100.00 | 43.50 | 94.28 | 390.58 | pCi/L |
| GROSS BETA | UPPER | 23 | 100.00 | 24.95 | 53.34 | 221.31 | pCi/L |
| PLUTONIUM-238 | UPPER | 15 | 100.00 | 0.00 | 0.01 | 0.03 | pCi/L |
| PLUTONIUM-239,240 | UPPER | 194 | 100.00 | 0.00 | 0.02 | 0.06 | pCi/L |
| RADIUM-226 | UPPER | 6 | 100.00 | 0.36 | 0.13 | 1.29 | pCi/L |
| STRONTIUM-89,90 | UPPER | 32 | 100.00 | 0.22 | 0.28 | 1.15 | pCi/L |
| TRITIUM | UPPER | 84 | 100.00 | 624.85 | 4,246.75 | 13,539.22 | pCi/L |
| URANIUM-233,234 | UPPER | 35 | 100.00 | 15.62 | 38.75 | 144.83 | pCi/L |
| URANIUM-235 | UPPER | 35 | 100.00 | 0.62 | 1.38 | 5.23 | pCi/L |
| URANIUM-238 | UPPER | 22 | 100.00 | 10.84 | 27.73 | 114.17 | pCi/L |



47

47/65

Table C-10. Groundwater UTLs by flow-system for water-quality parameters.

# UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GROUNDWATER, WATER-QUALITY PARAMETERS

| ANALYTE | FLOW-SYSTEM | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|---|
| ALKALINITY AS CACO3 | LOWER | 3 | 100.00 | 305,166.67 | 160,234.46 | 4,134,059.44 | UG/L |
| BICARBONATE | LOWER | 93 | 100.00 | 233,546.17 | 102,980.99 | 473,491.87 | UG/L |
| CARBONATE | LOWER | 92 | 28.26 | 3,318.77 | 4,245.24 | 13,210.17 | UG/L |
| CHLORIDE | LOWER | 79 | 96.20 | 100,205.95 | 128,066.02 | 489,654.73 | UG/L |
| FLUORIDE | LOWER | 92 | 97.83 | 949.35 | 465.34 | 2,033.58 | UG/L |
| NITRATE/NITRITE | LOWER | 90 | 78.89 | 861.22 | 945.96 | 3,737.87 | UG/L |
| NITRITE | LOWER | 16 | 56.25 | 190.62 | 295.19 | 1,407.78 | UG/L |
| ORTHOPHOSPHATE | LOWER | 54 | 61.11 | 18.46 | 10.16 | 50.52 | UG/L |
| PHOSPHORUS | LOWER | 14 | 64.29 | 173.57 | 264.99 | 1,322.89 | UG/L |
| SILICA | LOWER | 83 | 100.00 | 8,077.25 | 5,808.92 | 25,742.17 | UG/L |
| SULFATE | LOWER | 82 | 95.12 | 123,943.90 | 250,872.10 | 886,845.95 | UG/L |
| TOTAL DISSOLVED SOLIDS | LOWER | 94 | 100.00 | 545,138.30 | 445,290.59 | 1,582,665.38 | UG/L |
| TOTAL SOLIDS | LOWER | 5 | 80.00 | 318,240.00 | 356,657.98 | 3,506,414.55 | UG/L |
| TOTAL SUSPENDED SOLIDS | LOWER | 88 | 77.27 | 403,085.23 | 727,972.80 | 2,616,850.51 | UG/L |
| ALKALINITY AS CACO3 | UPPER | 3 | 100.00 | 156,900.00 | 158,643.41 | 3,947,773.53 | UG/L |
| BICARBONATE | UPPER | 311 | 100.00 | 223,807.08 | 151,717.58 | 577,309.04 | UG/L |
| CHLORIDE | UPPER | 257 | 92.61 | 12,241.67 | 12,930.51 | 42,369.76 | UG/L |
| FLUORIDE | UPPER | 300 | 97.67 | 611.07 | 472.04 | 1,710.92 | UG/L |
| NITRATE/NITRITE | UPPER | 305 | 81.64 | 1,048.34 | 1,807.86 | 5,260.65 | UG/L |
| NITRITE | UPPER | 54 | 37.04 | 27.94 | 38.25 | 148.61 | UG/L |
| ORTHOPHOSPHATE | UPPER | 191 | 53.40 | 15.05 | 17.47 | 55.76 | UG/L |
| PH | UPPER | 3 | 100.00 | 7.17 | 0.46 | 18.20 | UG/L |
| PHOSPHORUS | UPPER | 56 | 57.14 | 39.45 | 41.60 | 170.70 | UG/L |
| SILICA | UPPER | 274 | 100.00 | 14,082.92 | 8,075.96 | 32,899.91 | UG/L |
| SULFATE | UPPER | 278 | 99.64 | 86,370.14 | 174,613.96 | 493,220.67 | UG/L |
| TOTAL DISSOLVED SOLIDS | UPPER | 310 | 100.00 | 355,495.44 | 312,010.29 | 1,082,479.41 | UG/L |
| TOTAL SOLIDS | UPPER | 4 | 75.00 | 24,025.00 | 36,789.98 | 479,752.89 | UG/L |
| TOTAL SUSPENDED SOLIDS | UPPER | 301 | 80.07 | 133,396.64 | 429,323.86 | 1,133,721.25 | UG/L |



48

48/65

Table C-11. Geologic material UTLs by geologic unit for total metals.

## UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GEOLOGIC MATERIALS, TOTAL METALS

| ANALYTE | GEOLOGIC UNIT | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|---|
| ALUMINUM | COL | 28 | 100.00 | 10,541.43 | 4,945.95 | 27,861.88 | MG/KG |
| ARSENIC | COL | 28 | 85.71 | 3.57 | 1.74 | 9.65 | MG/KG |
| BARIUM | COL | 28 | 100.00 | 133.20 | 94.05 | 462.57 | MG/KG |
| BERYLLIUM | COL | 28 | 96.43 | 5.47 | 5.47 | 24.62 | MG/KG |
| CADMIUM | COL | 26 | 57.69 | 0.86 | 0.42 | 2.35 | MG/KG |
| CALCIUM | COL | 28 | 100.00 | 9,082.14 | 6,369.14 | 31,386.50 | MG/KG |
| CESIUM | COL | 24 | 75.00 | 206.24 | 56.88 | 413.26 | MG/KG |
| CHROMIUM | COL | 28 | 100.00 | 13.79 | 5.86 | 34.31 | MG/KG |
| COBALT | COL | 28 | 25.00 | 6.11 | 3.87 | 19.66 | MG/KG |
| COPPER | COL | 28 | 96.43 | 14.67 | 5.48 | 33.87 | MG/KG |
| IRON | COL | 28 | 100.00 | 15,028.07 | 6,715.26 | 38,544.51 | MG/KG |
| LEAD | COL | 28 | 100.00 | 16.23 | 4.62 | 32.40 | MG/KG |
| LITHIUM | COL | 28 | 28.57 | 8.52 | 7.56 | 34.99 | MG/KG |
| MAGNESIUM | COL | 28 | 78.57 | 2,987.32 | 1,577.90 | 8,513.05 | MG/KG |
| MANGANESE | COL | 28 | 100.00 | 191.87 | 160.26 | 753.10 | MG/KG |
| MERCURY | COL | 27 | 22.22 | 0.18 | 0.20 | 0.88 | MG/KG |
| NICKEL | COL | 28 | 92.86 | 16.97 | 8.28 | 45.97 | MG/KG |
| POTASSIUM | COL | 28 | 35.71 | 979.61 | 721.36 | 3,505.78 | MG/KG |
| SELENIUM | COL | 27 | 22.22 | 0.85 | 0.65 | 3.15 | MG/KG |
| SILVER | COL | 19 | 42.11 | 5.85 | 9.46 | 42.68 | MG/KG |
| STRONTIUM | COL | 28 | 85.71 | 55.92 | 27.04 | 150.63 | MG/KG |
| TIN | COL | 23 | 26.09 | 87.36 | 147.51 | 630.37 | MG/KG |
| VANADIUM | COL | 28 | 100.00 | 30.31 | 12.23 | 73.15 | MG/KG |
| ZINC | COL | 28 | 100.00 | 56.13 | 21.92 | 132.87 | MG/KG |
| ALUMINUM | RFA | 62 | 100.00 | 13,565.95 | 13,657.25 | 55,097.66 | MG/KG |
| ARSENIC | RFA | 62 | 69.35 | 4.15 | 5.70 | 21.48 | MG/KG |
| BARIUM | RFA | 62 | 83.87 | 84.46 | 100.14 | 388.97 | MG/KG |
| BERYLLIUM | RFA | 62 | 87.10 | 4.65 | 4.66 | 18.83 | MG/KG |
| CADMIUM | RFA | 46 | 47.83 | 0.84 | 0.48 | 2.36 | MG/KG |
| CALCIUM | RFA | 62 | 82.26 | 6,676.41 | 19,969.15 | 67,402.61 | MG/KG |
| CESIUM | RFA | 62 | 75.81 | 242.09 | 337.12 | 1,267.28 | MG/KG |
| CHROMIUM | RFA | 62 | 100.00 | 22.08 | 30.15 | 113.77 | MG/KG |
| COBALT | RFA | 62 | 35.48 | 8.76 | 13.16 | 48.79 | MG/KG |
| COPPER | RFA | 62 | 87.10 | 11.68 | 15.59 | 59.10 | MG/KG |
| IRON | RFA | 62 | 100.00 | 14,347.10 | 16,126.79 | 63,388.67 | MG/KG |
| LEAD | RFA | 62 | 100.00 | 9.05 | 7.07 | 30.54 | MG/KG |
| LITHIUM | RFA | 62 | 59.68 | 14.33 | 12.85 | 53.41 | MG/KG |
| MAGNESIUM | RFA | 62 | 58.06 | 2,482.38 | 4,093.78 | 14,931.58 | MG/KG |
| MANGANESE | RFA | 62 | 100.00 | 235.92 | 417.44 | 1,505.36 | MG/KG |
| MERCURY | RFA | 54 | 42.59 | 0.29 | 0.80 | 2.81 | MG/KG |
| NICKEL | RFA | 59 | 88.14 | 23.35 | 25.45 | 103.63 | MG/KG |
| POTASSIUM | RFA | 61 | 27.87 | 1,545.33 | 3,036.93 | 10,780.63 | MG/KG |
| SILVER | RFA | 55 | 30.91 | 2.48 | 5.55 | 19.99 | MG/KG |
| STRONTIUM | RFA | 62 | 30.65 | 77.93 | 87.02 | 342.55 | MG/KG |
| VANADIUM | RFA | 62 | 96.77 | 32.03 | 34.96 | 138.33 | MG/KG |
| ZINC | RFA | 61 | 93.44 | 29.97 | 61.25 | 216.23 | MG/KG |

Table C-11 (cont').

## UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GEOLOGIC MATERIALS, TOTAL METALS (CONT')

| ANALYTE | GEOLOGIC UNIT | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|---|
| ALUMINUM | WCS | 8 | 100.00 | 14,181.25 | 5,023.23 | 43,375.23 | MG/KG |
| ARSENIC | WCS | 9 | 77.78 | 2.94 | 1.55 | 11.27 | MG/KG |
| BARIUM | WCS | 9 | 88.89 | 64.81 | 26.27 | 206.40 | MG/KG |
| BERYLLIUM | WCS | 9 | 100.00 | 3.57 | 1.09 | 9.45 | MG/KG |
| CADMIUM | WCS | 9 | 22.22 | 0.63 | 0.27 | 2.06 | MG/KG |
| CALCIUM | WCS | 9 | 66.67 | 2,213.33 | 1,356.05 | 9,520.93 | MG/KG |
| CESIUM | WCS | 9 | 100.00 | 214.89 | 5.99 | 247.16 | MG/KG |
| CHROMIUM | WCS | 9 | 100.00 | 20.70 | 5.93 | 52.65 | MG/KG |
| COPPER | WCS | 9 | 100.00 | 12.14 | 5.91 | 43.99 | MG/KG |
| IRON | WCS | 9 | 100.00 | 14,262.22 | 4,066.80 | 36,177.70 | MG/KG |
| LEAD | WCS | 9 | 100.00 | 6.68 | 3.15 | 23.66 | MG/KG |
| MAGNESIUM | WCS | 9 | 55.56 | 2,033.89 | 1,253.36 | 8,788.12 | MG/KG |
| MANGANESE | WCS | 9 | 100.00 | 171.88 | 99.17 | 706.30 | MG/KG |
| NICKEL | WCS | 9 | 100.00 | 15.31 | 6.87 | 52.31 | MG/KG |
| SELENIUM | WCS | 9 | 66.67 | 1.95 | 1.25 | 8.71 | MG/KG |
| SILVER | WCS | 9 | 100.00 | 24.29 | 6.94 | 61.68 | MG/KG |
| TIN | WCS | 9 | 100.00 | 278.00 | 65.04 | 628.52 | MG/KG |
| VANADIUM | WCS | 9 | 100.00 | 31.42 | 11.01 | 90.76 | MG/KG |
| ZINC | WCS | 9 | 100.00 | 23.62 | 8.30 | 68.34 | MG/KG |
| ALUMINUM | KAR | 21 | 100.00 | 7,482.60 | 2,681.30 | 17,608.83 | MG/KG |
| ARSENIC | KAR | 21 | 66.67 | 3.72 | 3.26 | 16.05 | MG/KG |
| BARIUM | KAR | 21 | 95.24 | 99.40 | 55.10 | 307.51 | MG/KG |
| BERYLLIUM | KAR | 21 | 100.00 | 3.35 | 3.16 | 15.29 | MG/KG |
| CADMIUM | KAR | 19 | 57.89 | 0.83 | 0.37 | 2.28 | MG/KG |
| CALCIUM | KAR | 21 | 100.00 | 5,477.14 | 1,831.78 | 12,395.06 | MG/KG |
| CESIUM | KAR | 16 | 93.75 | 223.62 | 31.26 | 352.50 | MG/KG |
| CHROMIUM | KAR | 21 | 100.00 | 8.91 | 2.98 | 20.18 | MG/KG |
| COBALT | KAR | 21 | 23.81 | 6.74 | 7.20 | 33.94 | MG/KG |
| COPPER | KAR | 20 | 100.00 | 15.76 | 5.93 | 38.48 | MG/KG |
| IRON | KAR | 20 | 100.00 | 12,963.25 | 8,753.38 | 46,502.32 | MG/KG |
| LEAD | KAR | 21 | 100.00 | 18.91 | 6.19 | 42.29 | MG/KG |
| LITHIUM | KAR | 21 | 28.57 | 7.17 | 8.39 | 38.84 | MG/KG |
| MAGNESIUM | KAR | 21 | 66.67 | 2,053.71 | 1,213.43 | 6,636.37 | MG/KG |
| MANGANESE | KAR | 21 | 100.00 | 171.90 | 183.74 | 865.82 | MG/KG |
| MERCURY | KAR | 21 | 33.33 | 0.23 | 0.24 | 1.13 | MG/KG |
| NICKEL | KAR | 19 | 84.21 | 18.78 | 13.39 | 70.90 | MG/KG |
| SELENIUM | KAR | 19 | 31.58 | 0.90 | 1.01 | 4.85 | MG/KG |
| SILVER | KAR | 16 | 25.00 | 3.72 | 6.22 | 29.37 | MG/KG |
| STRONTIUM | KAR | 21 | 90.48 | 69.50 | 30.95 | 186.40 | MG/KG |
| VANADIUM | KAR | 20 | 90.00 | 20.70 | 8.76 | 54.25 | MG/KG |
| ZINC | KAR | 21 | 100.00 | 60.24 | 19.22 | 132.82 | MG/KG |

Table C-12. Geologic material UTLs by geologic unit for total radionuclides.

## UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

### GEOLOGIC MATERIALS, TOTAL RADIONUCLIDES

| ANALYTE | GEOLOGY | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | UTL 99 / 99 | UNITS |
|---|---|---|---|---|---|---|---|
| CESIUM-137 | COL | 28 | 100.00 | 0.01 | 0.04 | 0.17 | pCi/g |
| GROSS ALPHA | COL | 28 | 100.00 | 31.95 | 8.90 | 63.10 | pCi/g |
| GROSS BETA | COL | 28 | 100.00 | 27.00 | 3.52 | 39.32 | pCi/g |
| PLUTONIUM-239,240 | COL | 28 | 100.00 | 0.01 | 0.01 | 0.03 | pCi/g |
| RADIUM-226 | COL | 21 | 100.00 | 1.07 | 0.18 | 1.77 | pCi/g |
| RADIUM-228 | COL | 21 | 100.00 | 1.57 | 0.29 | 2.65 | pCi/g |
| STRONTIUM-89,90 | COL | 28 | 100.00 | -0.01 | 0.36 | 1.24 | pCi/g |
| TRITIUM | COL | 28 | 100.00 | 62.14 | 106.16 | 433.90 | pCi/g |
| URANIUM, TOTAL | COL | 28 | 100.00 | 1.86 | 0.73 | 4.41 | pCi/g |
| URANIUM-233,234 | COL | 28 | 100.00 | 1.14 | 1.58 | 6.66 | pCi/g |
| URANIUM-235 | COL | 28 | 100.00 | 0.04 | 0.06 | 0.24 | pCi/g |
| URANIUM-238 | COL | 28 | 100.00 | 0.94 | 0.34 | 2.15 | pCi/g |
| AMERICIUM-241 | RFA | 28 | 100.00 | -0.00 | 0.01 | 0.02 | pCi/g |
| CESIUM-137 | RFA | 62 | 100.00 | 0.01 | 0.04 | 0.14 | pCi/g |
| GROSS ALPHA | RFA | 62 | 100.00 | 22.32 | 8.18 | 47.21 | pCi/g |
| GROSS BETA | RFA | 62 | 100.00 | 24.10 | 6.75 | 44.62 | pCi/g |
| PLUTONIUM-239,240 | RFA | 62 | 100.00 | 0.00 | 0.01 | 0.02 | pCi/g |
| RADIUM-226 | RFA | 58 | 100.00 | 0.63 | 0.10 | 0.96 | pCi/g |
| RADIUM-228 | RFA | 58 | 100.00 | 1.34 | 0.31 | 2.32 | pCi/g |
| STRONTIUM-89,90 | RFA | 62 | 100.00 | 0.03 | 0.35 | 1.09 | pCi/g |
| TRITIUM | RFA | 62 | 100.00 | 172.90 | 122.68 | 545.96 | pCi/g |
| URANIUM, TOTAL | RFA | 62 | 100.00 | 1.29 | 0.81 | 3.76 | pCi/g |
| URANIUM-233,234 | RFA | 62 | 100.00 | 0.64 | 0.46 | 2.04 | pCi/g |
| URANIUM-235 | RFA | 62 | 100.00 | 0.01 | 0.03 | 0.11 | pCi/g |
| URANIUM-238 | RFA | 62 | 100.00 | 0.64 | 0.38 | 1.79 | pCi/g |
| CESIUM-137 | WCS | 9 | 100.00 | 0.01 | 0.03 | 0.19 | pCi/g |
| GROSS ALPHA | WCS | 9 | 100.00 | 20.89 | 5.88 | 52.59 | pCi/g |
| GROSS BETA | WCS | 9 | 100.00 | 21.89 | 5.53 | 51.70 | pCi/g |
| PLUTONIUM-239,240 | WCS | 9 | 100.00 | 0.01 | 0.01 | 0.07 | pCi/g |
| RADIUM-226 | WCS | 4 | 100.00 | 0.68 | 0.15 | 2.53 | pCi/g |
| RADIUM-228 | WCS | 4 | 100.00 | 1.42 | 0.29 | 4.98 | pCi/g |
| STRONTIUM-89,90 | WCS | 9 | 100.00 | 0.17 | 0.44 | 2.56 | pCi/g |
| TRITIUM | WCS | 9 | 100.00 | 174.44 | 114.47 | 791.30 | pCi/g |
| URANIUM, TOTAL | WCS | 9 | 100.00 | 1.36 | 0.21 | 2.50 | pCi/g |
| URANIUM-233,234 | WCS | 9 | 100.00 | 0.60 | 0.12 | 1.26 | pCi/g |
| URANIUM-235 | WCS | 9 | 100.00 | 0.02 | 0.07 | 0.38 | pCi/g |
| URANIUM-238 | WCS | 9 | 100.00 | 0.73 | 0.12 | 1.39 | pCi/g |
| CESIUM-137 | KAR | 21 | 100.00 | 0.00 | 0.00 | 0.00 | pCi/g |
| GROSS ALPHA | KAR | 21 | 100.00 | 29.98 | 8.42 | 61.78 | pCi/g |
| GROSS BETA | KAR | 21 | 100.00 | 25.76 | 3.85 | 40.29 | pCi/g |
| PLUTONIUM-239,240 | KAR | 21 | 100.00 | 0.00 | 0.01 | 0.03 | pCi/g |
| RADIUM-226 | KAR | 14 | 100.00 | 1.09 | 0.12 | 1.63 | pCi/g |
| RADIUM-228 | KAR | 14 | 100.00 | 1.30 | 0.19 | 2.14 | pCi/g |
| STRONTIUM-89,90 | KAR | 21 | 100.00 | -0.11 | 0.36 | 1.24 | pCi/g |
| TRITIUM | KAR | 21 | 100.00 | 65.95 | 122.69 | 529.32 | pCi/g |
| URANIUM, TOTAL | KAR | 21 | 100.00 | 1.96 | 0.64 | 4.40 | pCi/g |
| URANIUM-233,234 | KAR | 21 | 100.00 | 0.96 | 0.39 | 2.42 | pCi/g |
| URANIUM-235 | KAR | 21 | 100.00 | 0.04 | 0.08 | 0.35 | pCi/g |
| URANIUM-238 | KAR | 21 | 100.00 | 0.98 | 0.25 | 1.92 | pCi/g |

Table C-13. Geologic material UTLs by geologic unit for total "water-quality" parameters.

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GEOLOGIC MATERIALS, TOTAL "WATER-QUALITY" PARAMETERS

| ANALYTE | GEOLOGY | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | UTL 99 / 99 | UNITS |
|---|---|---|---|---|---|---|---|
| PH | COL | 28 | 100.00 | 8.26 | 0.45 | 5 / 10 | PH UNITS |
| SULFIDE | COL | 27 | 18.52 | 1.87 | 1.39 | 6.36 | MG/KG |
| PH | RFA | 60 | 100.00 | 7.97 | 0.77 | 5 / 10.4 | PH UNITS |
| SULFIDE | RFA | 53 | 32.08 | 2.27 | 3.02 | 30,082.97 | MG/KG |
| NITRATE/NITRITE | WCS | 9 | 33.33 | 1.08 | 0.62 | 4.44 | MG/KG |
| PH | WCS | 9 | 100.00 | 7.41 | 0.18 | 5 / 9 | PH UNITS |
| SULFIDE | WCS | 9 | 22.22 | 3.00 | 1.84 | 6.00 | MG/KG |
| PH | KAR | 21 | 100.00 | 8.43 | 0.87 | 5 / 11.7 | PH UNITS |



52

53/65

Table C-14.. Geologic material UTLs by flow-system for total metals.

## UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

### GEOLOGIC MATERIALS, TOTAL METALS

| ANALYTE | FLOW-SYSTEM | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|---|
| ALUMINUM | LOWER | 21 | 100.00 | 7,482.60 | 2,681.30 | 17,608.83 | MG/KG |
| ARSENIC | LOWER | 21 | 66.67 | 3.72 | 3.26 | 16.05 | MG/KG |
| BARIUM | LOWER | 21 | 95.24 | 99.40 | 55.10 | 307.51 | MG/KG |
| BERYLLIUM | LOWER | 21 | 100.00 | 3.35 | 3.16 | 15.29 | MG/KG |
| CADMIUM | LOWER | 19 | 57.89 | 0.83 | 0.37 | 2.28 | MG/KG |
| CALCIUM | LOWER | 21 | 100.00 | 5,477.14 | 1,831.78 | 12,395.06 | MG/KG |
| CESIUM | LOWER | 16 | 93.75 | 223.62 | 31.26 | 352.50 | MG/KG |
| CHROMIUM | LOWER | 21 | 100.00 | 8.91 | 2.98 | 20.18 | MG/KG |
| COBALT | LOWER | 21 | 23.81 | 6.74 | 7.20 | 33.94 | MG/KG |
| COPPER | LOWER | 20 | 100.00 | 15.76 | 5.93 | 38.48 | MG/KG |
| IRON | LOWER | 20 | 100.00 | 12,963.25 | 8,753.38 | 46,502.32 | MG/KG |
| LEAD | LOWER | 21 | 100.00 | 18.91 | 6.19 | 42.29 | MG/KG |
| LITHIUM | LOWER | 21 | 28.57 | 7.17 | 8.39 | 38.84 | MG/KG |
| MAGNESIUM | LOWER | 21 | 66.67 | 2,053.71 | 1,213.43 | 6,636.37 | MG/KG |
| MANGANESE | LOWER | 21 | 100.00 | 171.90 | 183.74 | 865.82 | MG/KG |
| MERCURY | LOWER | 21 | 33.33 | 0.23 | 0.24 | 1.13 | MG/KG |
| NICKEL | LOWER | 19 | 84.21 | 18.78 | 13.39 | 70.90 | MG/KG |
| SELENIUM | LOWER | 19 | 31.58 | 0.90 | 1.01 | 4.85 | MG/KG |
| SILVER | LOWER | 16 | 25.00 | 3.72 | 6.22 | 29.37 | MG/KG |
| STRONTIUM | LOWER | 21 | 90.48 | 69.50 | 30.95 | 186.40 | MG/KG |
| VANADIUM | LOWER | 20 | 90.00 | 20.70 | 8.76 | 54.25 | MG/KG |
| ZINC | LOWER | 21 | 100.00 | 60.24 | 19.22 | 132.82 | MG/KG |
| ALUMINUM | UPPER | 98 | 100.00 | 12,752.03 | 11,310.57 | 39,105.66 | MG/KG |
| ARSENIC | UPPER | 99 | 74.75 | 3.88 | 4.63 | 14.66 | MG/KG |
| BARIUM | UPPER | 99 | 88.89 | 96.46 | 96.46 | 321.20 | MG/KG |
| BERYLLIUM | UPPER | 99 | 90.91 | 4.78 | 4.71 | 15.75 | MG/KG |
| CADMIUM | UPPER | 81 | 48.15 | 0.82 | 0.44 | 2.17 | MG/KG |
| CALCIUM | UPPER | 99 | 85.86 | 6,951.09 | 16,215.59 | 44,733.41 | MG/KG |
| CESIUM | UPPER | 95 | 77.89 | 230.46 | 273.51 | 867.74 | MG/KG |
| CHROMIUM | UPPER | 99 | 100.00 | 19.61 | 24.33 | 76.30 | MG/KG |
| COBALT | UPPER | 99 | 30.30 | 7.50 | 10.77 | 32.60 | MG/KG |
| COPPER | UPPER | 99 | 90.91 | 12.57 | 12.82 | 42.43 | MG/KG |
| IRON | UPPER | 99 | 100.00 | 14,531.98 | 13,257.27 | 45,421.42 | MG/KG |
| LEAD | UPPER | 99 | 100.00 | 10.87 | 7.05 | 27.29 | MG/KG |
| LITHIUM | UPPER | 99 | 45.45 | 11.76 | 11.45 | 38.45 | MG/KG |
| MAGNESIUM | UPPER | 99 | 63.64 | 2,584.42 | 3,365.51 | 10,426.06 | MG/KG |
| MANGANESE | UPPER | 99 | 100.00 | 217.64 | 341.96 | 1,014.41 | MG/KG |
| MERCURY | UPPER | 86 | 33.72 | 0.24 | 0.64 | 2.20 | MG/KG |
| NICKEL | UPPER | 96 | 90.62 | 20.73 | 20.74 | 69.05 | MG/KG |
| POTASSIUM | UPPER | 98 | 28.57 | 1,311.57 | 2,442.62 | 7,002.88 | MG/KG |
| SELENIUM | UPPER | 82 | 25.61 | 1.22 | 1.79 | 6.68 | MG/KG |
| SILVER | UPPER | 83 | 40.96 | 5.62 | 9.46 | 34.39 | MG/KG |
| STRONTIUM | UPPER | 99 | 43.43 | 65.62 | 72.88 | 235.42 | MG/KG |
| TIN | UPPER | 92 | 22.83 | 61.75 | 112.28 | 323.37 | MG/KG |
| VANADIUM | UPPER | 99 | 97.98 | 31.49 | 28.50 | 97.89 | MG/KG |
| ZINC | UPPER | 98 | 95.92 | 36.86 | 51.12 | 155.97 | MG/KG |

Table C-15. Geologic material UTLs by flow-system for total radionuclides.

| UPPER TOLERANCE LIMITS BY FLOW-SYSTEM<br>GEOLOGIC MATERIALS, TOTAL RADIONUCLIDES | | | | | | | |
|---|---|---|---|---|---|---|---|
| ANALYTE | FLOW-SYSTEM | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | UTL 99 / 99 | UNITS |
| CESIUM-137 | LOWER | 21 | 100.00 | 0.00 | 0.00 | 0.00 | pCi/g |
| GROSS ALPHA | LOWER | 21 | 100.00 | 29.98 | 8.42 | 61.78 | pCi/g |
| GROSS BETA | LOWER | 21 | 100.00 | 25.76 | 3.85 | 40.29 | pCi/g |
| PLUTONIUM-239,240 | LOWER | 21 | 100.00 | 0.00 | 0.01 | 0.03 | pCi/g |
| RADIUM-226 | LOWER | 14 | 100.00 | 1.09 | 0.12 | 1.63 | pCi/g |
| RADIUM-228 | LOWER | 14 | 100.00 | 1.30 | 0.19 | 2.14 | pCi/g |
| STRONTIUM-89,90 | LOWER | 21 | 100.00 | -0.11 | 0.36 | 1.24 | pCi/g |
| TRITIUM | LOWER | 21 | 100.00 | 65.95 | 122.69 | 529.32 | pCi/g |
| URANIUM, TOTAL | LOWER | 21 | 100.00 | 1.96 | 0.64 | 4.40 | pCi/g |
| URANIUM-233,234 | LOWER | 21 | 100.00 | 0.96 | 0.39 | 2.42 | pCi/g |
| URANIUM-235 | LOWER | 21 | 100.00 | 0.04 | 0.08 | 0.35 | pCi/g |
| URANIUM-238 | LOWER | 21 | 100.00 | 0.98 | 0.25 | 1.92 | pCi/g |
| AMERICIUM-241 | UPPER | 28 | 100.00 | -0.00 | 0.01 | 0.02 | pCi/g |
| CESIUM-137 | UPPER | 99 | 100.00 | 0.01 | 0.04 | 0.11 | pCi/g |
| GROSS ALPHA | UPPER | 99 | 100.00 | 24.91 | 9.28 | 49.48 | pCi/g |
| GROSS BETA | UPPER | 99 | 100.00 | 24.72 | 6.06 | 40.75 | pCi/g |
| PLUTONIUM-239,240 | UPPER | 99 | 100.00 | 0.00 | 0.01 | 0.02 | pCi/g |
| RADIUM-226 | UPPER | 83 | 100.00 | 0.75 | 0.23 | 1.45 | pCi/g |
| RADIUM-228 | UPPER | 83 | 100.00 | 1.40 | 0.32 | 2.37 | pCi/g |
| STRONTIUM-89,90 | UPPER | 99 | 100.00 | 0.03 | 0.36 | 0.98 | pCi/g |
| TRITIUM | UPPER | 99 | 100.00 | 141.72 | 126.75 | 477.09 | pCi/g |
| URANIUM, TOTAL | UPPER | 99 | 100.00 | 1.46 | 0.79 | 3.55 | pCi/g |
| URANIUM-233,234 | UPPER | 99 | 100.00 | 0.78 | 0.93 | 3.25 | pCi/g |
| URANIUM-235 | UPPER | 99 | 100.00 | 0.02 | 0.05 | 0.14 | pCi/g |
| URANIUM-238 | UPPER | 99 | 100.00 | 0.73 | 0.38 | 1.73 | pCi/g |

Table C-16. Geologic material UTLs by flow-system for total "water-quality" parameters.

| UPPER TOLERANCE LIMITS BY FLOW-SYSTEM<br>TOTAL "WATER-QUALITY" PARAMETERS | | | | | | | |
|---|---|---|---|---|---|---|---|
| ANALYTE | FLOW-SYSTEM | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | UTL 99 / 99 | UNITS |
| PH | LOWER | 21 | 100.00 | 8.43 | 0.87 | 11.73 | PH UNIT |
| PH | UPPER | 97 | 100.00 | 8.00 | 0.69 | 9.61 | PH UNIT |
| SULFIDE | UPPER | 88 | 27.27 | 2.22 | 2.52 | 9.88 | MG/KG |

Table C-17. Stream water UTLs for dissolved metals.

UPPER TOLERANCE LIMITS (SITE-WIDE)

STREAM WATER, DISSOLVED METALS

| ANALYTE | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|
| ALUMINUM | 134 | 41.79 | 89.80 | 165.40 | 475.18 | UG/L |
| ANTIMONY | 92 | 29.35 | 18.01 | 17.68 | 59.20 | UG/L |
| BARIUM | 145 | 57.24 | 45.17 | 35.44 | 127.74 | UG/L |
| CALCIUM | 154 | 93.51 | 23,621.75 | 11,474.97 | 50,358.44 | UG/L |
| COPPER | 125 | 37.60 | 5.90 | 4.97 | 17.48 | UG/L |
| IRON | 153 | 68.63 | 144.92 | 178.41 | 560.62 | UG/L |
| LEAD | 113 | 27.43 | 1.33 | 1.63 | 5.14 | UG/L |
| LITHIUM | 119 | 33.61 | 15.71 | 20.58 | 63.66 | UG/L |
| MAGNESIUM | 150 | 76.67 | 4,735.82 | 2,173.67 | 9,800.47 | UG/L |
| MANGANESE | 149 | 71.14 | 28.02 | 47.73 | 139.22 | UG/L |
| PHOSPHORUS | 6 | 100.00 | 194.83 | 124.91 | 1,111.00 | UG/L |
| POTASSIUM | 126 | 51.59 | 1,427.16 | 926.51 | 3,585.92 | UG/L |
| SELENIUM | 85 | 25.88 | 2.24 | 3.63 | 13.26 | UG/L |
| SODIUM | 153 | 94.12 | 16,603.04 | 7,508.05 | 34,096.80 | UG/L |
| STRONTIUM | 139 | 69.06 | 241.81 | 313.57 | 972.43 | UG/L |
| TIN | 99 | 21.21 | 28.52 | 23.40 | 83.05 | UG/L |
| ZINC | 139 | 58.99 | 13.59 | 18.14 | 55.86 | UG/L |

Table C-18. Stream water UTLs for total metals.

UPPER TOLERANCE LIMITS (SITE-WIDE)

STREAM WATER, TOTAL METALS

| ANALYTE | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|
| ALUMINUM | 139 | 78.42 | 747.63 | 1,349.84 | 3,892.76 | UG/L |
| ARSENIC | 110 | 27.27 | 1.73 | 1.76 | 5.84 | UG/L |
| BARIUM | 131 | 68.70 | 58.84 | 34.02 | 138.11 | UG/L |
| CALCIUM | 153 | 94.77 | 23,601.21 | 11,100.19 | 49,464.66 | UG/L |
| COPPER | 121 | 41.32 | 5.59 | 4.87 | 16.95 | UG/L |
| IRON | 157 | 89.81 | 1,247.08 | 2,866.81 | 7,926.75 | UG/L |
| LEAD | 131 | 35.88 | 1.88 | 2.35 | 7.36 | UG/L |
| LITHIUM | 126 | 41.27 | 11.77 | 17.42 | 52.35 | UG/L |
| MAGNESIUM | 146 | 81.51 | 4,901.94 | 2,107.61 | 9,812.65 | UG/L |
| MANGANESE | 151 | 78.81 | 84.76 | 343.57 | 885.29 | UG/L |
| PHOSPHORUS | 6 | 83.33 | 186.25 | 138.68 | 1,203.40 | UG/L |
| POTASSIUM | 128 | 57.03 | 1,669.97 | 1,071.73 | 4,167.09 | UG/L |
| SELENIUM | 120 | 21.67 | 1.55 | 2.05 | 6.33 | UG/L |
| SILICON | 67 | 100.00 | 6,076.23 | 3,377.17 | 16,346.19 | UG/L |
| SODIUM | 155 | 92.90 | 16,060.41 | 7,620.96 | 33,817.24 | UG/L |
| STRONTIUM | 135 | 63.70 | 171.63 | 179.61 | 590.13 | UG/L |
| TIN | 118 | 20.34 | 20.18 | 20.13 | 67.07 | UG/L |
| VANADIUM | 120 | 27.50 | 6.97 | 9.36 | 28.76 | UG/L |
| ZINC | 151 | 67.55 | 31.91 | 61.69 | 175.64 | UG/L |

Table C-19. Stream water UTLs for dissolved radionuclides.

## UPPER TOLERANCE LIMITS (SITE-WIDE)

### STREAM WATER, DISSOLVED RADIONUCLIDES

| ANALYTE | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|
| AMERICIUM-241 | 84 | 100.00 | 0.07 | 0.13 | 0.59 | pCi/L |
| CESIUM-134 | 3 | 100.00 | 2.27 | 0.10 | 4.67 | pCi/L |
| CESIUM-137 | 10 | 100.00 | 0.82 | 1.22 | 6.99 | pCi/L |
| GROSS ALPHA | 61 | 100.00 | 1.81 | 8.85 | 28.71 | pCi/L |
| GROSS BETA | 61 | 100.00 | 4.69 | 6.78 | 25.30 | pCi/L |
| GROSS GAMMA | 24 | 100.00 | 0.70 | 0.25 | 1.63 | pCi/L |
| PLUTONIUM-236 | 4 | 100.00 | 0.00 | 0.01 | 0.07 | pCi/L |
| PLUTONIUM-238 | 4 | 100.00 | 0.01 | 0.01 | 0.07 | pCi/L |
| PLUTONIUM-239,240 | 36 | 100.00 | 0.12 | 0.20 | 0.79 | pCi/L |
| RADIUM-226 | 3 | 100.00 | 0.19 | 0.21 | 5.23 | pCi/L |
| RADIUM-228 | 2 | 100.00 | 1.05 | 0.49 | 92.93 | pCi/L |
| STRONTIUM-89,90 | 87 | 100.00 | 0.73 | 0.55 | 2.42 | pCi/L |
| TRITIUM | 56 | 100.00 | 185.58 | 416.00 | 1,498.07 | pCi/L |
| URANIUM, TOTAL | 6 | 100.00 | 0.72 | 0.48 | 4.27 | pCi/L |
| URANIUM-233,234 | 56 | 100.00 | 0.92 | 4.21 | 14.20 | pCi/L |
| URANIUM-235 | 56 | 100.00 | 0.14 | 0.20 | 0.78 | pCi/L |
| URANIUM-238 | 56 | 100.00 | 0.71 | 3.24 | 10.93 | pCi/L |

Table C-20. Stream water UTLs for total radionuclides.

## UPPER TOLERANCE LIMITS (SITE-WIDE)

### STREAM WATER, TOTAL RADIONUCLIDES

| ANALYTE | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|
| AMERICIUM-241 | 106 | 100.00 | 0.00 | 0.01 | 0.02 | pCi/g |
| CESIUM-134 | 8 | 100.00 | 1.53 | 1.29 | 9.04 | pCi/g |
| CESIUM-137 | 93 | 100.00 | 0.23 | 0.60 | 1.63 | pCi/g |
| GROSS ALPHA | 88 | 100.00 | 2.96 | 8.25 | 28.06 | pCi/g |
| GROSS BETA | 84 | 100.00 | 5.49 | 8.17 | 30.35 | pCi/g |
| PLUTONIUM-236 | 12 | 100.00 | -0.00 | 0.00 | 0.01 | pCi/g |
| PLUTONIUM-238 | 12 | 100.00 | -0.00 | 0.01 | 0.03 | pCi/g |
| PLUTONIUM-239,240 | 105 | 100.00 | 0.00 | 0.01 | 0.02 | pCi/g |
| RADIUM-226 | 4 | 100.00 | 1.07 | 1.25 | 16.56 | pCi/g |
| STRONTIUM-89,90 | 75 | 100.00 | 0.92 | 1.30 | 4.88 | pCi/g |
| TRITIUM | 73 | 100.00 | 75.71 | 209.22 | 711.94 | pCi/g |
| URANIUM, TOTAL | 17 | 100.00 | 0.59 | 0.52 | 2.69 | pCi/g |
| URANIUM-233,234 | 79 | 100.00 | 0.49 | 0.55 | 2.16 | pCi/g |
| URANIUM-235 | 75 | 100.00 | 0.05 | 0.07 | 0.28 | pCi/g |
| URANIUM-238 | 55 | 100.00 | 0.36 | 0.43 | 1.73 | pCi/g |

Table C-21. Stream water UTLs for water-quality parameters.

UPPER TOLERANCE LIMITS (SITE-WIDE)

STREAM WATER, WATER-QUALITY PARAMETERS

| ANALYTE | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|
| BICARBONATE | 154 | 100.00 | 97,571.20 | 40,237.29 | 191,324.06 | UG/L |
| CARBONATE | 154 | 24.03 | 2,999.74 | 1,937.53 | 7,514.19 | UG/L |
| CBOD5 | 10 | 100.00 | 7,635.00 | 3,912.66 | 27,486.77 | UG/L |
| CHLORIDE | 151 | 92.05 | 16,833.01 | 15,608.95 | 53,201.88 | UG/L |
| CYANIDE | 129 | 31.01 | 2,221.93 | 5,220.92 | 14,386.67 | UG/L |
| DISSOLVED ORGANIC CARBON | 35 | 100.00 | 6,102.57 | 3,267.38 | 16,997.16 | UG/L |
| FLUORIDE | 100 | 98.00 | 338.41 | 107.90 | 589.81 | UG/L |
| NITRATE/NITRITE | 153 | 56.86 | 324.55 | 438.84 | 1,347.05 | UG/L |
| NITRITE | 85 | 22.35 | 13.98 | 14.74 | 58.81 | UG/L |
| OIL AND GREASE | 105 | 33.33 | 4,024.29 | 3,756.06 | 12,775.89 | UG/L |
| PH | 51 | 98.04 | 7.34 | 0.63 | 9.32 | PH UNITS |
| PHOSPHORUS | 102 | 35.29 | 43.68 | 55.07 | 171.98 | UG/L |
| SILICA | 95 | 97.89 | 11,128.11 | 7,265.36 | 28,056.40 | UG/L |
| SULFATE | 151 | 98.01 | 18,782.45 | 8,174.66 | 37,829.40 | UG/L |
| TOTAL DISSOLVED SOLIDS | 151 | 100.00 | 170,119.21 | 56,721.65 | 302,280.65 | UG/L |
| TOTAL ORGANIC CARBON | 49 | 100.00 | 7,466.94 | 4,621.53 | 22,047.87 | UG/L |
| TOTAL SUSPENDED SOLIDS | 159 | 59.75 | 18,677.99 | 45,772.72 | 125,528.42 | UG/L |

Table C-22. Seep/spring water UTLs for dissolved metals.

UPPER TOLERANCE LIMITS (SITE-WIDE)

SEEP / SPRING WATER, DISSOLVED METALS

| ANALYTE | SAMPLE SIZE, N. | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|
| ALUMINUM | 43 | 25.58 | 42.77 | 30.04 | 137.54 | UG/L |
| ANTIMONY | 30 | 30.00 | 25.89 | 28.49 | 124.08 | UG/L |
| BARIUM | 47 | 44.68 | 71.95 | 42.39 | 205.69 | UG/L |
| CALCIUM | 50 | 98.00 | 50,222.00 | 34,498.38 | 159,064.39 | UG/L |
| COPPER | 41 | 24.39 | 3.01 | 5.51 | 23.40 | UG/L |
| IRON | 49 | 69.39 | 1,927.00 | 4,082.76 | 14,808.10 | UG/L |
| LEAD | 42 | 21.43 | 1.08 | 0.86 | 3.81 | UG/L |
| LITHIUM | 43 | 32.56 | 29.46 | 20.72 | 94.84 | UG/L |
| MAGNESIUM | 47 | 72.34 | 7,002.07 | 5,198.40 | 23,403.02 | UG/L |
| MANGANESE | 44 | 86.36 | 127.57 | 185.52 | 712.90 | UG/L |
| MERCURY | 22 | 22.73 | 0.18 | 0.26 | 1.16 | UG/L |
| MOLYBDENUM | 34 | 20.59 | 33.81 | 21.07 | 104.49 | UG/L |
| POTASSIUM | 39 | 41.03 | 1,389.94 | 1,640.62 | 6,745.06 | UG/L |
| SODIUM | 50 | 98.00 | 12,297.00 | 5,585.54 | 29,919.38 | UG/L |
| STRONTIUM | 45 | 77.78 | 481.40 | 401.87 | 1,749.29 | UG/L |
| ZINC | 46 | 45.65 | 15.68 | 21.13 | 82.33 | UG/L |

Table C-23. Seep/spring water UTLs for total metals.

UPPER TOLERANCE LIMITS (SITE-WIDE)

SEEP / SPRING WATER, TOTAL METALS

| ANALYTE | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|
| ALUMINUM | 48 | 83.33 | 18,115.18 | 47,149.24 | 166,871.02 | UG/L |
| ANTIMONY | 34 | 32.35 | 46.68 | 108.89 | 411.91 | UG/L |
| ARSENIC | 44 | 59.09 | 69.77 | 192.06 | 675.73 | UG/L |
| BARIUM | 44 | 75.00 | 913.39 | 1,692.11 | 6,252.00 | UG/L |
| BERYLLIUM | 38 | 34.21 | 2.81 | 3.37 | 13.86 | UG/L |
| CADMIUM | 33 | 30.30 | 9.08 | 17.25 | 67.29 | UG/L |
| CALCIUM | 53 | 90.57 | 94,329.72 | 128,636.27 | 500,177.15 | UG/L |
| CESIUM | 33 | 24.24 | 419.98 | 449.37 | 1,936.79 | UG/L |
| CHROMIUM | 40 | 40.00 | 23.69 | 49.27 | 183.74 | UG/L |
| COBALT | 35 | 34.29 | 43.39 | 90.97 | 346.73 | UG/L |
| COPPER | 44 | 52.27 | 43.89 | 99.94 | 359.20 | UG/L |
| CYANIDE | 5 | 40.00 | 5.95 | 7.48 | 72.83 | UG/L |
| IRON | 51 | 88.24 | 175,074.71 | 518,671.63 | 1,811,483.71 | UG/L |
| LEAD | 45 | 66.67 | 91.14 | 207.26 | 745.05 | UG/L |
| LITHIUM | 35 | 48.57 | 29.43 | 26.57 | 118.02 | UG/L |
| MAGNESIUM | 50 | 80.00 | 10,370.60 | 7,644.36 | 34,488.56 | UG/L |
| MANGANESE | 51 | 80.39 | 1,798.04 | 5,027.04 | 17,658.34 | UG/L |
| MOLYBDENUM | 33 | 27.27 | 33.46 | 39.12 | 165.51 | UG/L |
| NICKEL | 35 | 37.14 | 50.68 | 116.39 | 438.78 | UG/L |
| POTASSIUM | 41 | 48.78 | 3,386.23 | 3,069.81 | 13,071.50 | UG/L |
| SELENIUM | 36 | 38.89 | 3.31 | 3.72 | 15.64 | UG/L |
| SILICON | 11 | 100.00 | 8,408.18 | 3,027.84 | 23,029.71 | UG/L |
| SILVER | 32 | 31.25 | 10.05 | 25.69 | 97.35 | UG/L |
| SODIUM | 53 | 88.68 | 12,005.80 | 5,016.89 | 27,834.09 | UG/L |
| STRONTIUM | 42 | 61.90 | 506.16 | 476.35 | 2,009.06 | UG/L |
| TIN | 35 | 37.14 | 94.03 | 190.89 | 730.54 | UG/L |
| VANADIUM | 41 | 51.22 | 117.09 | 280.76 | 1,002.88 | UG/L |
| ZINC | 50 | 82.00 | 195.22 | 431.42 | 1,556.36 | UG/L |

Table C-24. Seep/spring water UTLs for dissolved radionuclides.

| UPPER TOLERANCE LIMITS (SITE-WIDE) SEEP / SPRING WATER, DISSOLVED RADIONUCLIDES | | | | | | |
|---|---|---|---|---|---|---|
| ANALYTE | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
| AMERICIUM-241 | 8 | 100.00 | 0.13 | 0.28 | 1.76 | pCi/L |
| CESIUM-137 | 3 | 100.00 | -0.27 | 0.21 | 4.71 | pCi/L |
| GROSS ALPHA | 13 | 100.00 | 2.78 | 5.21 | 26.09 | pCi/L |
| GROSS BETA | 14 | 100.00 | 5.94 | 10.09 | 49.69 | pCi/L |
| GROSS GAMMA | 5 | 100.00 | 1.09 | 1.25 | 12.27 | pCi/L |
| PLUTONIUM-239,240 | 8 | 100.00 | 0.10 | 0.16 | 1.02 | pCi/L |
| RADIUM-226 | 2 | 100.00 | 0.99 | 1.30 | 242.36 | pCi/L |
| STRONTIUM-89,90 | 20 | 100.00 | 0.52 | 0.39 | 2.01 | pCi/L |
| TRITIUM | 13 | 100.00 | 301.25 | 298.70 | 1,637.06 | pCi/L |
| URANIUM, TOTAL | 3 | 100.00 | 1.90 | 2.43 | 59.89 | pCi/L |
| URANIUM-233,234 | 13 | 100.00 | 0.91 | 0.73 | 4.19 | pCi/L |
| URANIUM-235 | 12 | 100.00 | 0.12 | 0.13 | 0.72 | pCi/L |
| URANIUM-238 | 13 | 100.00 | 0.60 | 0.54 | 3.03 | pCi/L |

Table C-25. Seep/spring water UTLs for total radionuclides.

| UPPER TOLERANCE LIMITS (SITE-WIDE) SEEP / SPRING WATER, TOTAL RADIONUCLIDES | | | | | | |
|---|---|---|---|---|---|---|
| ANALYTE | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
| AMERICIUM-241 | 37 | 100.00 | 0.01 | 0.02 | 0.08 | pCi/L |
| CESIUM-137 | 37 | 100.00 | 0.58 | 1.99 | 7.16 | pCi/L |
| GROSS ALPHA | 36 | 100.00 | 42.52 | 89.77 | 340.13 | pCi/L |
| GROSS BETA | 10 | 100.00 | 2.15 | 1.50 | 9.74 | pCi/L |
| PLUTONIUM-239,240 | 33 | 100.00 | 0.21 | 0.78 | 2.85 | pCi/L |
| RADIUM-226 | 12 | 100.00 | 7.72 | 9.10 | 49.88 | pCi/L |
| RADIUM-228 | 5 | 100.00 | 16.38 | 14.11 | 142.53 | pCi/L |
| STRONTIUM-89,90 | 32 | 100.00 | 0.32 | 0.38 | 1.61 | pCi/L |
| TRITIUM | 31 | 100.00 | -87.72 | 1,275.95 | 4,277.76 | pCi/L |
| URANIUM, TOTAL | 9 | 100.00 | 0.85 | 0.63 | 4.23 | pCi/L |
| URANIUM-233,234 | 33 | 100.00 | 0.64 | 1.29 | 4.99 | pCi/L |
| URANIUM-235 | 32 | 100.00 | 0.02 | 0.08 | 0.31 | pCi/L |
| URANIUM-238 | 28 | 100.00 | 0.64 | 1.21 | 4.89 | pCi/L |



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Table C-26. Seep/spring water UTLs for water-quality parameters.

UPPER TOLERANCE LIMITS (SITE-WIDE)

SEEP / SPRING WATER, WATER-QUALITY PARAMETERS

| ANALYTE | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|
| BICARBONATE | 50 | 100.00 | 321,640.17 | 574,658.46 | 2,105,321.61 | UG/L |
| CARBONATE | 55 | 43.64 | 4,495.68 | 4,965.08 | 20,160.52 | UG/L |
| CHLORIDE | 53 | 90.57 | 12,523.58 | 17,061.93 | 66,353.96 | UG/L |
| CYANIDE | 46 | 26.09 | 7.11 | 7.00 | 29.21 | UG/L |
| DISSOLVED ORGANIC CARBON | 5 | 100.00 | 5,000.00 | 2,236.07 | 24,988.27 | UG/L |
| FLUORIDE | 18 | 100.00 | 552.22 | 264.88 | 1,601.23 | UG/L |
| NITRATE/NITRITE | 53 | 60.38 | 945.19 | 2,118.91 | 7,630.34 | UG/L |
| OIL AND GREASE | 24 | 37.50 | 2,448.13 | 1,934.86 | 9,490.08 | UG/L |
| PH | 35 | 100.00 | 7.22 | 0.43 | 8.64 | PH UNITS |
| PHOSPHORUS | 18 | 61.11 | 354.94 | 804.15 | 3,539.67 | UG/L |
| SILICA | 17 | 100.00 | 17,025.45 | 8,569.50 | 51,617.95 | UG/L |
| SULFATE | 53 | 96.23 | 46,962.26 | 87,305.62 | 322,411.50 | UG/L |
| TOTAL DISSOLVED SOLIDS | 53 | 100.00 | 263,867.92 | 174,307.09 | 813,806.81 | UG/L |
| TOTAL ORGANIC CARBON | 7 | 100.00 | 9,014.29 | 3,184.56 | 29,433.51 | UG/L |
| TOTAL SUSPENDED SOLIDS | 54 | 87.04 | 2,712,305.56 | 7,791,125.40 | 27,293,306.20 | UG/L |



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Table C-27. Stream sediment UTLs for total metals.

UPPER TOLERANCE LIMITS (SITE-WIDE)

STREAM SEDIMENTS, TOTAL METALS

| ANALYTE | SAMPLE SIZE, N | PERCENT-DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|
| ALUMINUM | 59 | 100.00 | 5,887.61 | 4,912.73 | 21,387.27 | MG/KG |
| ANTIMONY | 52 | 44.23 | 4.55 | 4.16 | 17.68 | MG/KG |
| ARSENIC | 59 | 69.49 | 2.24 | 2.50 | 10.13 | MG/KG |
| BARIUM | 57 | 84.21 | 74.47 | 56.85 | 253.82 | MG/KG |
| BERYLLIUM | 57 | 63.16 | 0.93 | 3.40 | 11.65 | MG/KG |
| CADMIUM | 51 | 39.22 | 0.72 | 0.58 | 2.55 | MG/KG |
| CALCIUM | 59 | 81.36 | 3,554.57 | 4,719.98 | 18,446.12 | MG/KG |
| CESIUM | 56 | 62.50 | 101.77 | 107.96 | 442.39 | MG/KG |
| CHROMIUM | 59 | 84.75 | 8.25 | 7.49 | 31.88 | MG/KG |
| COBALT | 59 | 76.27 | 5.16 | 3.57 | 16.43 | MG/KG |
| COPPER | 59 | 83.05 | 10.81 | 8.23 | 36.78 | MG/KG |
| IRON | 59 | 100.00 | 8,852.63 | 6,263.19 | 28,612.98 | MG/KG |
| LEAD | 59 | 100.00 | 22.02 | 36.79 | 138.09 | MG/KG |
| LITHIUM | 57 | 91.23 | 10.01 | 9.83 | 41.01 | MG/KG |
| MAGNESIUM | 59 | 79.66 | 1,404.18 | 1,253.37 | 5,358.56 | MG/KG |
| MANGANESE | 59 | 100.00 | 229.52 | 214.85 | 907.35 | MG/KG |
| MERCURY | 49 | 48.98 | 0.12 | 0.11 | 0.46 | MG/KG |
| MOLYBDENUM | 58 | 53.45 | 5.48 | 8.33 | 31.75 | MG/KG |
| NICKEL | 57 | 75.44 | 7.01 | 5.44 | 24.16 | MG/KG |
| POTASSIUM | 58 | 70.69 | 812.50 | 743.98 | 3,159.74 | MG/KG |
| SELENIUM | 58 | 43.10 | 0.45 | 0.55 | 2.18 | MG/KG |
| SILICON | 19 | 100.00 | 331.53 | 362.31 | 1,741.79 | MG/KG |
| SILVER | 54 | 33.33 | 0.86 | 0.71 | 3.11 | MG/KG |
| SODIUM | 59 | 79.66 | 161.47 | 136.80 | 593.09 | MG/KG |
| STRONTIUM | 58 | 89.66 | 45.62 | 77.91 | 291.42 | MG/KG |
| THALLIUM | 50 | 24.00 | 0.34 | 0.24 | 1.10 | MG/KG |
| TIN | 54 | 53.70 | 9.69 | 9.79 | 40.57 | MG/KG |
| VANADIUM | 57 | 91.23 | 18.15 | 14.34 | 63.39 | MG/KG |
| ZINC | 58 | 98.28 | 44.44 | 29.98 | 139.04 | MG/KG |



61

61/65

Table C-28. Stream sediment UTLs for total radionuclides.

| UPPER TOLERANCE LIMITS (SITE-WIDE)<br>STREAM SEDIMENTS, TOTAL RADIONUCLIDES | | | | | | |
|---|---|---|---|---|---|---|
| ANALYTE | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
| AMERICIUM-241 | 37 | 100.00 | 0.17 | 0.48 | 1.77 | pCi/g |
| CESIUM-137 | 35 | 100.00 | 0.26 | 0.38 | 1.54 | pCi/g |
| GROSS ALPHA | 45 | 100.00 | 22.98 | 20.46 | 87.54 | pCi/g |
| GROSS BETA | 43 | 100.00 | 35.35 | 9.98 | 66.83 | pCi/g |
| PLUTONIUM-238 | 5 | 100.00 | 0.00 | 0.00 | 0.00 | pCi/g |
| PLUTONIUM-239,240 | 45 | 100.00 | 0.54 | 1.61 | 5.62 | pCi/g |
| RADIUM-226 | 21 | 100.00 | 0.85 | 0.36 | 2.22 | pCi/g |
| RADIUM-228 | 20 | 100.00 | 1.70 | 0.74 | 4.55 | pCi/g |
| STRONTIUM-89,90 | 43 | 100.00 | 0.21 | 0.27 | 1.07 | pCi/g |
| TRITIUM | 42 | 100.00 | 194.30 | 265.07 | 1,030.59 | pCi/g |
| URANIUM, TOTAL | 6 | 100.00 | 1.48 | 0.69 | 6.57 | pCi/g |
| URANIUM-233,234 | 47 | 100.00 | 1.68 | 1.15 | 5.29 | pCi/g |
| URANIUM-235 | 49 | 100.00 | 0.06 | 0.05 | 0.21 | pCi/g |
| URANIUM-238 | 36 | 100.00 | 1.40 | 1.03 | 4.82 | pCi/g |

Table C-29. Stream sediment UTLs for total "water-quality" parameters.

| UPPER TOLERANCE LIMITS (SITE-WIDE)<br>STREAM SEDIMENTS, TOTAL "WATER-QUALITY" PARAMETERS | | | | | | |
|---|---|---|---|---|---|---|
| ANALYTE | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
| ALKALINITY AS CACO3 | 28 | 92.86 | 1,970.44 | 5,102.72 | 19,839.86 | MG/KG |
| BICARBONATE AS CACO3 | 4 | 100.00 | 1,041.25 | 1,449.27 | 18,993.76 | MG/KG |
| NITRATE/NITRITE | 52 | 71.15 | 7.76 | 15.67 | 57.19 | MG/KG |
| NITRITE | 12 | 83.33 | 0.34 | 0.19 | 1.21 | MG/KG |
| PH | 51 | 100.00 | 7.26 | 0.66 | 9.34 | PH UNITS |
| TOTAL ALKALINITY | 6 | 100.00 | 4,470.00 | 8,116.00 | 63,997.31 | MG/KG |



62

62/65

Table C-30. Seep/spring sediment UTLs for total metals.

## UPPER TOLERANCE LIMITS (SITE-WIDE)

SEEP / SPRING SEDIMENTS, TOTAL METALS

| ANALYTE | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|
| ALUMINUM | 20 | 100.00 | 10,354.30 | 5,010.71 | 29,553.14 | MG/KG |
| ANTIMONY | 18 | 44.44 | 8.81 | 8.14 | 41.84 | MG/KG |
| ARSENIC | 20 | 90.00 | 12.55 | 14.28 | 67.25 | MG/KG |
| BARIUM | 20 | 95.00 | 204.61 | 155.62 | 800.88 | MG/KG |
| BERYLLIUM | 16 | 81.25 | 1.13 | 0.92 | 4.94 | MG/KG |
| CADMIUM | 16 | 43.75 | 1.65 | 1.66 | 8.52 | MG/KG |
| CALCIUM | 20 | 100.00 | 19,407.50 | 16,059.56 | 80,940.62 | MG/KG |
| CESIUM | 17 | 52.94 | 260.47 | 200.55 | 1,070.01 | MG/KG |
| CHROMIUM | 18 | 94.44 | 10.98 | 5.27 | 31.87 | MG/KG |
| COBALT | 19 | 84.21 | 8.47 | 5.48 | 29.81 | MG/KG |
| COPPER | 18 | 94.44 | 18.74 | 10.68 | 61.04 | MG/KG |
| IRON | 18 | 100.00 | 20,763.89 | 22,673.64 | 110,559.63 | MG/KG |
| LEAD | 18 | 100.00 | 36.37 | 22.64 | 126.03 | MG/KG |
| LITHIUM | 18 | 88.89 | 19.79 | 20.12 | 99.49 | MG/KG |
| MAGNESIUM | 20 | 80.00 | 2,249.30 | 1,152.86 | 6,666.56 | MG/KG |
| MANGANESE | 19 | 100.00 | 261.63 | 273.79 | 1,327.33 | MG/KG |
| MERCURY | 15 | 33.33 | 0.23 | 0.31 | 1.55 | MG/KG |
| MOLYBDENUM | 19 | 57.89 | 15.77 | 19.74 | 92.59 | MG/KG |
| NICKEL | 17 | 88.24 | 12.99 | 7.51 | 43.31 | MG/KG |
| POTASSIUM | 18 | 61.11 | 1,050.72 | 616.83 | 3,493.61 | MG/KG |
| SELENIUM | 19 | 68.42 | 1.25 | 0.98 | 5.07 | MG/KG |
| SILICON | 10 | 100.00 | 1,698.70 | 2,117.17 | 12,440.63 | MG/KG |
| SILVER | 15 | 46.67 | 2.15 | 1.98 | 10.49 | MG/KG |
| SODIUM | 20 | 60.00 | 251.62 | 294.04 | 1,378.24 | MG/KG |
| STRONTIUM | 20 | 90.00 | 113.70 | 92.03 | 466.32 | MG/KG |
| THALLIUM | 13 | 30.77 | 1.42 | 2.44 | 12.33 | MG/KG |
| TIN | 19 | 57.89 | 22.18 | 18.75 | 95.16 | MG/KG |
| VANADIUM | 19 | 100.00 | 27.63 | 14.21 | 82.96 | MG/KG |
| ZINC | 20 | 100.00 | 56.13 | 22.67 | 143.00 | MG/KG |

Table C-31. Seep/spring sediment UTLs for total radionuclides.

## UPPER TOLERANCE LIMITS (SITE-WIDE)

SEEP / SPRING SEDIMENTS, TOTAL RADIONUCLIDES

| ANALYTE | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|
| AMERICIUM-241 | [illegible] | 100.00 | 0.13 | 0.34 | 1.46 | pCi/g |
| CESIUM-137 | 13 | 100.00 | 0.81 | 0.60 | 3.51 | pCi/g |
| GROSS ALPHA | 15 | 100.00 | 19.71 | 14.00 | 78.83 | pCi/g |
| GROSS BETA | 14 | 100.00 | 23.73 | 5.08 | 45.76 | pCi/g |
| PLUTONIUM-238 | 3 | 100.00 | 0.00 | 0.00 | 0.01 | pCi/g |
| PLUTONIUM-239,240 | 16 | 100.00 | 0.61 | 1.71 | 7.68 | pCi/g |
| RADIUM-226 | 9 | 100.00 | 0.71 | 0.24 | 1.97 | pCi/g |
| RADIUM-228 | 9 | 100.00 | 1.18 | 0.32 | 2.88 | pCi/g |
| STRONTIUM-89,90 | 14 | 100.00 | 0.35 | 0.52 | 2.63 | pCi/g |
| TRITIUM | 13 | 100.00 | 198.54 | 127.73 | 769.75 | pCi/g |
| URANIUM, TOTAL | 3 | 100.00 | 1.87 | 0.59 | 15.87 | pCi/g |
| URANIUM-233,234 | 16 | 100.00 | 0.82 | 0.38 | 2.39 | pCi/g |
| URANIUM-235 | 17 | 100.00 | 0.04 | 0.05 | 0.25 | pCi/g |
| URANIUM-238 | 14 | 100.00 | 0.73 | 0.41 | 2.52 | pCi/g |

Table C-32. Seep/spring sediment UTLs for total "water-quality" parameters.

## UPPER TOLERANCE LIMITS (SITE-WIDE)

SEEP / SPRING SEDIMENTS, "WATER-QUALITY" PARAMETERS

| ANALYTE | SAMPLE SIZE, N | PERCENT DETECTS | MEAN | STANDARD DEVIATION | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|
| ALKALINITY AS CACO3 | 8 | 100.00 | 14,192.25 | 27,343.99 | 173,110.00 | MG/KG |
| NITRATE/NITRITE | 17 | 52.94 | 4.14 | 3.90 | 19.89 | MG/KG |
| NITRITE | 3 | 100.00 | 1.33 | 1.53 | 37.91 | MG/KG |
| PH | 18 | 100.00 | 7.24 | 0.56 | 9.47 | PH UNITS |
| TOTAL ALKALINITY | 4 | 75.00 | 750.25 | 1,499.83 | 19,329.11 | MG/KG |



64

6/1/65

## SURFICIAL SOILS FROM ROCK CREEK

### TOTAL METALS

| Analyte | MEAN | STD DEV | N | TOL FACT | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|
| Aluminum | 12992.9 | 2251.53 | 18 | 3.9604 | 21909.86 | MG/KG |
| Antimony | 10.525 | 1.724 | 18 | 3.9604 | 17.35 | MG/KG |
| Arsenic | 5.817 | 1.818 | 18 | 3.9604 | 13.02 | MG/KG |
| Barium | 195.2 | 84.63 | 18 | 3.9604 | 530.37 | MG/KG |
| Beryllium | 0.983 | 0.256 | 18 | 3.9604 | 2.00 | MG/KG |
| Cadmium | 1.048 | 0.362 | 17 | 4.0367 | 2.51 | MG/KG |
| Calcium | 5068.1 | 2220.5 | 18 | 3.9604 | 13862.17 | MG/KG |
| Cesium | 61.43 | 61.43 | 18 | 3.9604 | 304.72 | MG/KG |
| Chromium | 15.207 | 2.798 | 19 | 3.8924 | 26.10 | MG/KG |
| Cobalt | 7.78 | 4.305 | 18 | 3.9604 | 24.83 | MG/KG |
| Copper | 12.964 | 3.629 | 18 | 3.9604 | 27.34 | MG/KG |
| Iron | 15381.7 | 3226.62 | 18 | 3.9604 | 28160.41 | MG/KG |
| Lead | 37.535 | 6.024 | 18 | 3.9604 | 61.39 | MG/KG |
| Lithium | 10.98 | 2.273 | 18 | 3.9604 | 19.98 | MG/KG |
| Magnesium | 2853.3 | 1049.95 | 18 | 3.9604 | 7011.52 | MG/KG |
| Manganese | 443.67 | 457.01 | 18 | 3.9604 | 2253.61 | MG/KG |
| Mercury | 0.09256 | 0.0306 | 18 | 3.9604 | 0.21 | MG/KG |
| Molybdenum | 3.31997 | 1.59652 | 18 | 3.9604 | 9.64 | MG/KG |
| Nickel | 12.578 | 3.588 | 18 | 3.9604 | 26.79 | MG/KG |
| Potassium | 2977.9 | 575.47 | 18 | 3.9604 | 5256.99 | MG/KG |
| Selenium | 0.4785 | 0.1468 | 18 | 3.9604 | 1.06 | MG/KG |
| Silicon | 780.99 | 700.452 | 18 | 3.9604 | 3555.06 | MG/KG |
| Silver | 1.726 | 0.693 | 18 | 3.9604 | 4.47 | MG/KG |
| Sodium | 175.14 | 75.031 | 18 | 3.9604 | 472.29 | MG/KG |
| Strontium | 35.331 | 13.811 | 18 | 3.9604 | 90.03 | MG/KG |
| Thallium | 0.3773 | 0.1204 | 18 | 3.9604 | 0.85 | MG/KG |
| Tin | 38.346 | 9.2105 | 18 | 3.9604 | 74.82 | MG/KG |
| Vanadium | 31.603 | 6.049 | 18 | 3.9604 | 55.56 | MG/KG |
| Zinc | 55.824 | 7.795 | 18 | 3.9604 | 86.70 | MG/KG |

## SURFICIAL SOILS FROM ROCK CREEK

### TOTAL RADIONUCLIDES

| Analyte | MEAN | STD DEV | N | TOL FACT | 99 / 99 UTL | UNITS |
|---|---|---|---|---|---|---|
| Americium-241 | 0.01854 | 0.0092 | 15 | 4.2224 | 0.06 | PCI/G |
| Cesium-137 | 1.41 | 0.4897 | 12 | 4.633 | 3.68 | PCI/G |
| Gross alpha | 19.825 | 4.916 | 10 | 5.0737 | 44.77 | PCI/G |
| Gross beta | 32.031 | 5.699 | 19 | 3.8924 | 54.21 | PCI/G |
| Plutonium-239,240 | 0.05523 | 0.02023 | 18 | 3.9604 | 0.14 | PCI/G |
| Radium-226 | 0.94538 | 0.12813 | 10 | 5.0737 | 1.60 | PCI/G |
| Radium-228 | 2.1767 | 0.5309 | 10 | 5.0737 | 4.87 | PCI/G |
| Strontium-89,90 | 0.61833 | 0.29768 | 9 | 5.3889 | 2.22 | PCI/G |
| Uranium-233,234 | 1.14497 | 0.15557 | 16 | 4.1233 | 1.79 | PCI/G |
| Uranium-235 | 0.05263 | 0.03271 | 16 | 4.1233 | 0.19 | PCI/G |
| Uranium-238 | 1.18301 | 0.18799 | 16 | 4.1233 | 1.96 | PCI/G |

Where "TOL FACT" is the tolerance factor for the 99/99 UTL and "STD DEV" is the standard deviation for sample size, N. The 99/99 UTL is calculated as (TOL FACT * STD DEV) + MEAN. Metals are 89-percent validated, and radionuclides are 64-percent validated in this table.